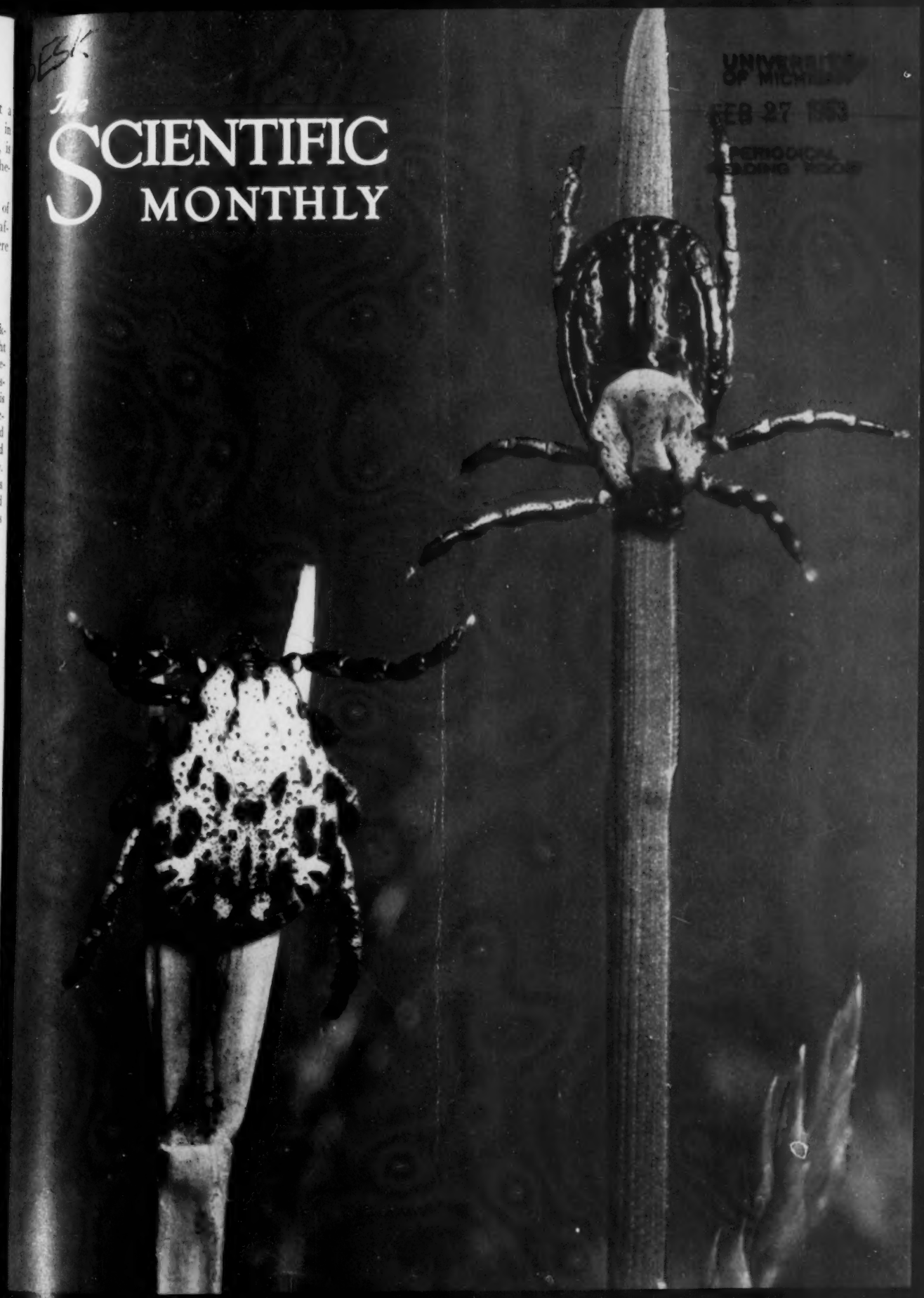


UNIVERSITY OF MICHIGAN
FEB 27 1953
PERIODICAL READING ROOM

TOUGH JACKETED CORD
MORE EFFICIENT RECEIVER WITH WIDER FREQUENCY RANGE
MORE POWERFUL TRANSMITTER
PROTECTED FROM HIGH LEVEL SURGES
RINGER WITH VOLUME CONTROL
LIGHTER HANDSET
VOICE LOUDNESS LESS AFFECTED BY DISTANCE
ADAPTABLE TO 10 CLASSES OF SERVICE
DIAL EASIER TO READ

New "500" telephone. It has already been introduced on a limited scale and will be put in use as opportunity permits, in places where it can serve best. Note new dial and 25 per cent lighter handset.

It adds miles to your voice

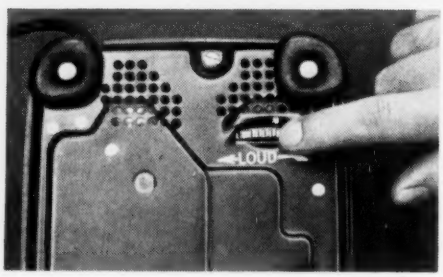
For years the telephone you know and use has done its job well—and still does. But as America grows, more people are settling in suburban areas. Telephone lines must be longer; more voice energy is needed to span the extra miles.

Bell Telephone Laboratories developed a new telephone which can deliver a voice ten times more powerfully. Outlying points may now be served without the installation of extra-heavy wires or special batteries on subscribers' premises. For shorter distances, the job can be done with thinner wires than before. Thus thousands of tons of copper and other strategic materials are being conserved.

The new telephone shows once again how Bell Telephone Laboratories keeps making telephony better while the cost stays low.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.



Adjustable volume control on bottom of new telephone permits subscriber to set it to ring as loudly or softly as he pleases. Ring is pleasant and harmonious, yet stands out clearer.

QUICK FACTS ON NEW TELEPHONE

Transmitter is much more powerful, due largely to increased sound pressure at the diaphragm and more efficient use of the carbon granules that turn sound waves into electrical impulses.

Light ring armature diaphragm receiver produces three times as much acoustic energy for the same input power. It transmits more of the high frequencies.

Improved dial mechanism can send pulses over greater distances to operate switches in dial exchange.

Built-in varistors equalize current, so voices don't get too loud close to telephone offices.

Despite increased sensitivity of receiver, "clicks" are subdued by copper oxide varistor which chops off peaks of current surges.

THE SCIENTIFIC MONTHLY

VOL. LXXVI FEBRUARY 1953 NO. 2

Contents

Enlarged *Dermacentor andersoni* Adults in "Waiting Position" . . . . . Cover
(Rocky Mountain Laboratory Photo)

Education for Survival . . . . . *Cornelis W. de Kiewiet* 57

Two Views for a Parallax (*Verse*) . . . . . *Gemma d'Auria* 62

Herodotus on Biology . . . . . *L. P. Coonen* 63

Oldest Material: Newest Uses . . . . . *Williams Haynes* 71

Tick Talk . . . . . *Cornelius B. Philip* 77

The Role of Cybernetics in Physiology . . . . *Stanton H. Cohn* and *Sylva M. Cohn* 85

The Engineer and the Fundamental Sciences . . . . . *C. G. Suits* 90

Atomic Scientist (*Verse*) . . . . . *Daniel Smythe* 99

Information Processing in Social and Industrial Research . . . *James L. McPherson, Samuel N. Alexander, H. Burke Horton,* and *Ezra Glaser* 100

Science on the March:

Biotic Change in New Zealand . . . . . *John H. Davis, Jr.* 109

Book Reviews by *G. B. Bachman, M. W. Ball, P. G. Bergmann, R. W. Bunting, K. E. Caster, H. S. M. Coxeter, T. De Vries, W. Haynes, N. Kornblum, M. E. Rose, P. L. Seman, H. H. Storch, N. Taylor, D. ter Haar,* and *J. A. Young* 112

Association Affairs 123

GLADYS M. KEENER, Executive Editor

EDITORIAL BOARD OF THE AAAS

(Terms expire June 30, 1953)

HOWARD A. MEYERHOFF, *Chairman*
WILLIAM R. AMBERSON
WALLACE R. BRODE
BENTLEY GLASS
K. LARK-HOROVITZ
WALTER J. NICKERSON

F. A. MOULTON, Advertising Representative

Established 1872 as *The Popular Science Monthly*; since 1915 an official publication of the American Association for the Advancement of Science.

Publication office, Business Press, Inc., 10 McGovern Ave., Lancaster, Pa. Orders for subscriptions and requests for change of address should be directed to the Circulation Department, A.A.A.S., 1515 Massachusetts Ave., N.W., Washington 5, D. C. Subscriptions: $7.50 per year; single copies 75 cents. Four weeks are required to effect change of address.

Address all correspondence concerning editorial matters and advertising to THE SCIENTIFIC MONTHLY, 1515 Massachusetts Ave., N.W., Washington 5, D. C. The editors are not responsible for loss or injury of manuscripts and photographs while in their possession or in transit; all manuscripts should be accompanied by return postage. The American Association for the Advancement of Science assumes no responsibility for the statements and opinions expressed by contributors.

Copyright, 1953, by the American Association for the Advancement of Science. Entered as second-class matter at the Post Office at Lancaster, Pa., December 30, 1947, under the Act of March 3, 1879. Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2) Section 34.40 P.L. & R. of 1948. Indexed in the *Reader's Guide to Periodical Literature*. The A.A.A.S. also publishes SCIENCE. Subscription and advertising rates on request.

Cable address: ADVANCESCI.

Science and Technology

(From the Month's News Releases)

Certified Weather Protection

A rubber-based masonry paint that will protect stucco, cement, building blocks, asbestos-cement shingles, and brick against the elements comes in decorator-styled colors. It is proof also against the destructive elements of lime, alkali, and moisture present in the masonry itself and is simple to apply by brush, roller, or spray.

Ultra-Automatic Viscosity Probes

Systems for continuous automatic viscosity measurement to 650° F and 1000 psi have no moving parts and are no larger than a fountain pen. One computer and multiplex unit located up to one mile from probes indicates viscosity measured by any desired instrument, or automatically records viscosities singly or in sequence on standard multipoint industrial recorders. As many as 16 kettles, reactors, or pipelines can be monitored.

Seeing Double

A magnifier that consists of two lenses folds flat and permits accurate readings on both sides of a duplex slide rule. A special type for pocket-sized rules has a magnifying power of three times. Four other sizes are available: 1 15/16″, 1 5/8″, 1 9/16″, and 1 3/8″.

Laboratory Latch

A Neoprene cylinder mounted inside a cupboard door, with a plunger screwed into the door, is flexible and trouble-free. The adjustable tension holds heavy doors securely, small doors gently. The latch can be adapted for metal cupboards.

Little Audrey

Bell Telephone Laboratories have developed "Audrey," an automatic digit recognizer, in which a special circuit automatically determines which of ten numbers from 1 to 0 has been spoken into an ordinary telephone. Although the time is far in the future when one may be connected with the person at the other end of the line simply by speaking the desired number into a telephone mouthpiece, still it is not too soon to hope that this miracle may come to pass.

Bind Your Own Manuscripts

With a plastic binding kit you can make those loose sheets of notes into an attractive booklet with red, white, or blue binders and free-turning pages that lie flat. As many as 15 pages may be punched at one time.

The Chemical Age

A few drops of Quel, shaken into a garbage container, eliminate all offensive odors (the manufacturer says). In addition, Quel acts to destroy garbage larvae and prevent their formation. It repels rats, flies, ants, field mice, and other rodents, but is harmless to domestic pets.

A combination of solder with its accompanying flux in the form of a paste permits single-handed soldering. Merely paint on the paste and apply heat from any source, from an oxyacetylene torch to a candle—even a cigarette lighter. A low melting point makes the solder ideal for emergency repairs.

A chemical fluid applied on dust cloths and mops absorbs instead of scatters dust and causes no stains or spots.

Wanted: Twins

The Department of Agriculture is asking for identical twin calves not more than four months old—preferably Aberdeen Angus, Herefords, or Shorthorns, although grades or crossbreds of any of these or other breeds can be used—for a continuation of feeding experiments begun in 1950. Breeders within 200 miles of Washington, D. C., who have such calves, should write to C. F. Winchester, Bureau of Animal Industry, Beltsville, Md.

Neat and Tidy Storage

A 128-drawer cabinet contains 384 compartments for the storage of small parts or similar items. Plastic drawers make visual selection and filing easy, although index slots are provided. A built-in safety catch allows open drawers to hang out for ready access, but prevents spillage. Eight smaller models are also available.

Paint Can Attachment

A pouring spout that prevents paint from spilling over when pouring or mixing also keeps the sealing groove free from paint and fits all gallon cans. Excess paint may be squeezed from the brush without slopping up the entire can.

Pocket Magnifier

An inexpensive, 10-power magnifier is designed for on-the-job inspection of small parts, castings, small joints and welds, and for reading micrometer and other fine scales. Weighing only 2½ ounces, the instrument may be clipped to the pocket like a fountain pen.

Stitch in Time

Chuck holes and breaks in concrete floors can be repaired in 15–30 minutes with a self-bonding, self-leveling, oil-resistant quick-setting cement. Lightweight equipment, such as hand rails, partitions, pipe flanges, or theatre seats, may be secured by means of anchor

---

Address a post card to Science and Technology, 1515 Massachusetts Ave., N.W., Washington 5, D. C., for further information about any item on pages iv and v.

bolts to concrete which, within an hour, will have a guaranteed compression strength of 4500 psi.

The Walk that Moves

A moving rubber sidewalk, the world's first, has been installed in Chicago's Museum of Science and Industry, as part of the exhibit of the B. F. Goodrich Company, the "Story of Rubber." Although it will be used only to move people through a part of the museum, it illustrates a practical means of rapidly transporting large numbers of people short distances in congested areas.

Color Video

A natural color television installation in the hospital of the University of Pennsylvania is making surgical procedures vivid to students in the university's schools of medicine. The TV equipment represents a gift of special apparatus contributed by friends of I. S. Ravdin, a pioneer in the development of color telecasts of surgical operations.

Accentuate the Positive

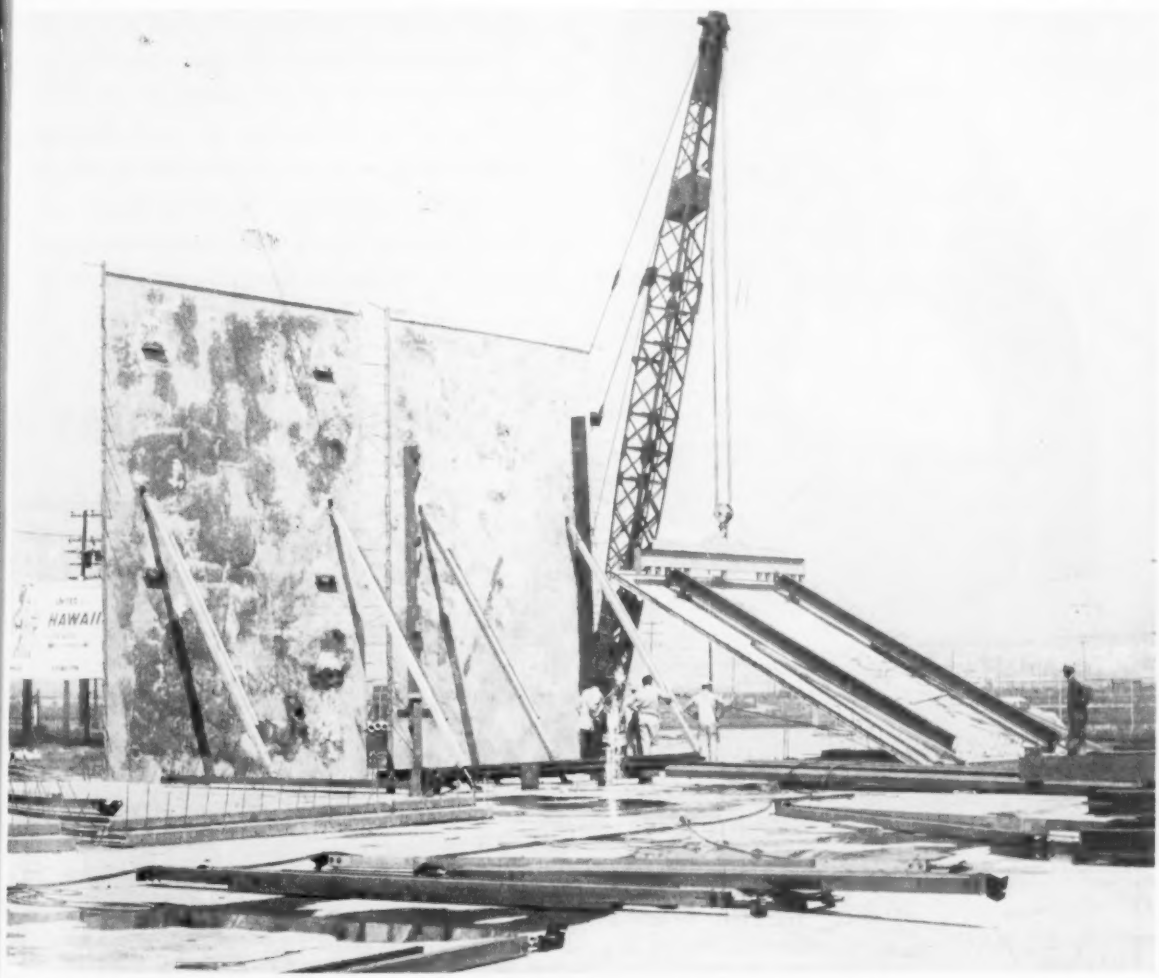
A new electric typewriter produces bold-face or regular typed copy at the touch of a key. Anything needing visual emphasis, such as statistical material, printers' copy, manuscripts, sales letters, and lists of names and addresses are among possible applications.

End Thermometer Breakage

A small stainless steel clamp has just enough tension to hold a thermometer firmly in an upright position, convenient for reading, and attaches to any beaker. It may also be used to hold glass stirring rods and metal electrodes in position.

Inventory Punched Cards

Based on the use of split tags, printed and punched from the receiving report by a marking machine, a system of unit control of all merchandise produces sales reports at high speed. Style, size, color, type, and fabric reports can also be assembled in the same way.



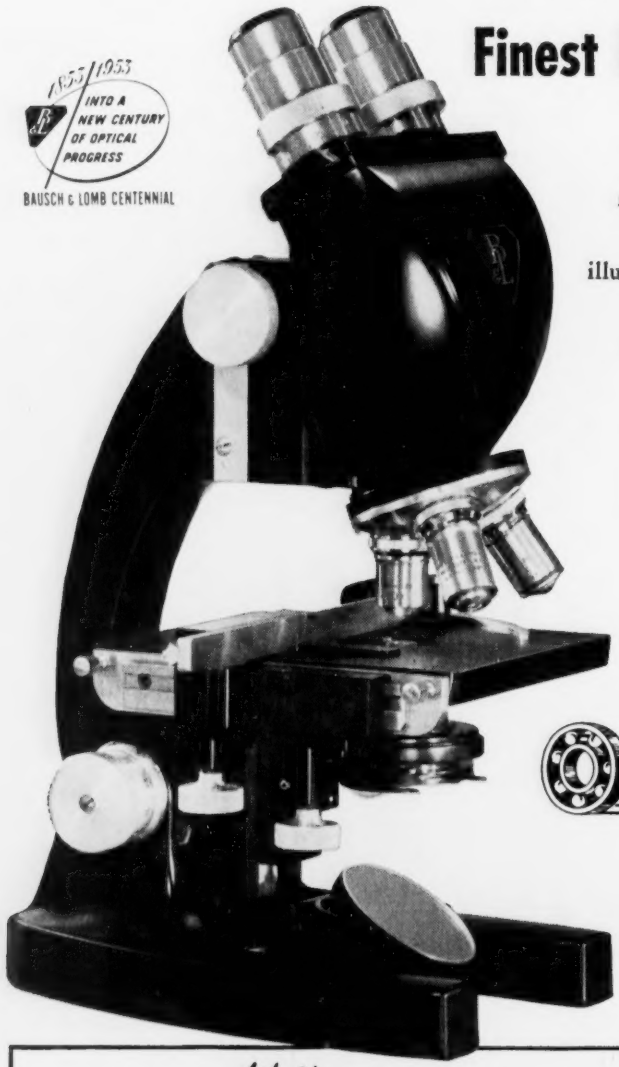
Twenty-eight foot walls, perhaps the tallest ever raised by the tilt-wall method of construction, are hoisted into place by giant cranes at the San Francisco maintenance base of United Air Lines. The six-inch thick slabs of reinforced concrete, poured into molds right at the hoisting point, weigh 19 tons.

Comfort Wins

HANDS DOWN

...with the World's Finest Laboratory Microscope

1853 1953 INTO A NEW CENTURY OF OPTICAL PROGRESS
BAUSCH & LOMB CENTENNIAL



Your hand is *completely at rest* on the table for relaxed operation of fine adjustment, mechanical stage and substage condenser controls, and illuminator switch. *They're all within effortless reach!* You remain fatigue-free, for more thorough examinations. And you'll appreciate the smooth, frictionless Dynoptic focusing motion. Start enjoying the many exclusive advantages of the *world's finest laboratory microscope.*

BAUSCH & LOMB

Dynoptic

LABORATORY MICROSCOPES

B&L

Write **for FREE DEMONSTRATION and LITERATURE.**
See for yourself how Bausch & Lomb Dynoptic Microscopes out-perform any laboratory microscope ever made. Bausch & Lomb Optical Co., 77114 St. Paul St., Rochester 2, N. Y.

THE
SCIENTIFIC MONTHLY

FEBRUARY 1953

Education for Survival

CORNELIS W. DE KIEWIET

Born in Rotterdam in 1902, the author spent his childhood in Johannesburg. He was educated at the universities of Witwatersrand, London, Paris, and Berlin. After teaching at the University of Witwatersrand and in Salisbury, Southern Rhodesia, he came to the United States in 1929, where he joined the staff of the Department of History of the State University of Iowa. In 1948 Dr. de Kiewiet went to Cornell as professor of modern European history and became, successively, dean of the College of Arts and Sciences, provost, and acting president, until called to serve as president of the University of Rochester in 1951. His article is based on an address given during the AAAS St. Louis meeting last December, at the Conference on Scientific Manpower, jointly sponsored by Section M, the AAAS Cooperative Committee on the Teaching of Science and Mathematics, and the Engineering Manpower Commission.

THE investigation which has been proceeding for a number of years into the nature and distribution of talent and skill in American society has given me a feeling of excitement and satisfaction. We are beginning to lay bare the anatomy of our skilled manpower. It is urgent that these studies be further pursued and refined. It is even more urgent that no opportunity be lost to draw public attention to these findings, and to stimulate a discussion of them. Wherever there are faculties or legislatures or other groups who have a stake in quality or productivity or efficiency, these findings and their meaning should be brought to their attention.

Education is especially indebted to the careful research into our national manpower. We have acquired a most effective reinforcement of the claims of higher education through this dissection of the body of national proficiency and competence, disclosing leanness and occasional fatness, constrictions and disproportions, inadequacy and new opportunity. The nourishment of ability which we call education is being freshly justified and stimulated. This is service of a high order. No faculty or legislature or foundation can properly be indifferent to the meaning of the findings that are being reached.

As in some of our natural resources, so now in our human resources, the time has come for a more precise accounting. We can no longer afford to waste or neglect available resources of human skill. It has suddenly become clear that as a nation we are still too casual, too inexpert, too wasteful, in our attitude toward brains and ability. Because

we have never lost a war, because we are almost continental in our extent, because more than any other people we have turned the raw earth into a flood of food and goods, we are in real danger of living in a world of false proportions, and of acquiring the delusion that we can always be adequate to the tasks thrust upon us. Today we must accept new magnitudes and make new comparisons. In the days of our relative isolation the millions of our population seemed more than sufficient by the side of the great Western European nations with which we compared ourselves. In fact, we considered ourselves so well endowed that, in an ungenerous immigration policy, we applied an embargo against the most precious of all commodities—human beings. For our lack of imagination we are today paying a heavy price.

New magnitudes and comparisons have suddenly been forced upon us. The rise of Russia and the collapse of the British position in the modern world have rent the veil which a sense of remoteness and security had placed between America and the masses of Asia, Eastern Europe, and Africa. Today American life is intimately confronted by the greater magnitudes and multitudes of China, India, Russia, and the Arab world. Even when we apply to these proportions the correction represented by differences in health, longevity, education, and industrial power, it is still evident that the comparisons and proportions of the contemporary world cause deep disquiet. In its world America is a minority group.

A characteristic error has already crept into the debate on manpower. This is the assumption that problems can be solved by legislation and governmental agencies. Federal control of education and federal direction of skilled manpower policies are not very different from one another. There is no substitute for a far-ranging national concern. There is still a great deal of ignorance and indifference even in universities and colleges about the skilled manpower needs of the country. It is false to assume that with an ample supply of students, higher education can therefore undertake to provide an adequate flow of trained people who will be reasonably well distributed in those areas where they are most urgently needed. Neither the social sciences nor the humanities have done nearly as well as the physical and natural sciences in adapting teaching and research to the new context in which American society has its being. In the environment of modern America, we must continually remind ourselves, are the new proportions of Russia, China, and India, the confusion of the buckling imperialisms of Western Europe, an ominous power vacuum in the Indian Ocean and the Middle East, and an unexpectedly early insurgence in Africa and the Arab world. Yet it cannot be claimed that our curricula have sufficiently modified the traditional emphasis upon the life and thought of the North Atlantic rim in order to pay due attention to the new "factors of modern history." Even those centers of study in Southeast Asia, China, or the Middle East which the foundations have providently helped to establish often suffer from a polite neutrality with which faculties isolate them from the main currents of teaching. It is urgent that there be a proper balance between the various skills by which a nation is made strong. It is therefore equally urgent that each of the great disciplines see that it is ready to perform its task.

A major part of the discussion on skilled manpower has been concerned with science and technology. This is understandable, especially if we assume that war is imminent and inevitable. The requirements of war make a balanced and farsighted manpower policy excessively difficult and probably impossible. Beyond military conscription itself, there must be a vast commitment of trained men to the machines that sustain war. To build a modern jet plane, over one hundred times as many engineer hours are required as were necessary twelve years ago. An hour's flight by a jet airplane demands forty hours of ground maintenance. The more complex the machine the greater the tail of skills which, like a comet, it must bear behind it.

American national policy, however, still assumes that war is not inevitable. Wisdom dictates two sets of concessions in order to establish a reasonable balance between the skilled manpower needs of a nation facing the possibility of war and the manpower needs of a nation that cannot abandon its deep hope for peace. There must be trained soldiers, a flow of engineers, assistance for essential industry, the sponsorship of scientific research. But if we are to cope with historic tasks comparable only with those shouldered by Rome or Great Britain at the height of their power we need a supply of knowledge and experience far beyond present levels. Even a world war, if that must be our fate, needs men who know geography, languages, and historical traditions. Although we might explode our way through to a military victory, illiteracy in these things would, as has happened before, turn the greatest victory into defeat.

The simple equation of a skilled manpower policy with the flow of soldiers, scientists, and en-

gineers is both wrong and dangerous. The total policy of a nation is too important and complicated to be guided solely by the recommendations of generals and engineering deans. We could perhaps listen more readily to their statements if the physical force we now possess or can readily develop were really the measure of our power and influence in the modern world. Never in modern times has a nation possessed so much physical power and yet been so baffled in the conduct of its foreign policy. The vast sum of atomic bombs and jet airplanes, of guided missiles and supercarriers and retired generals, cannot release a single American citizen from a Czech prison, or secure a visa for an American scholar to visit Russia. (The outstanding discovery of the past few years was made by a journalist named Oatis. He discovered the powerlessness of the atomic bomb.) Incomparably the most remarkable phenomenon in the modern world is precisely this lack of any equation between nuclear fission and the forces of history. A study of the experience of France or Great Britain in the past twenty-five years makes it plain that the compulsion to mobilize the total power of a nation in war is itself a defeat which an ultimate military victory cannot redress. Great Britain did not win the first world war in 1918. She lost it in 1914. To lose the peace is the great disaster. It is of the utmost importance for us to recognize that the pressure of events in the Arab world, in India, China, and even in Africa, cannot be controlled or guided in any chosen direction by the traditional forms of military action. Nor can the United States of America follow the old logic of imperialism which the Dutch followed when they took the place of the Portuguese in the seventeenth century, and which the British followed in the eighteenth century when they took over colonial control from Spain and France. The forms of action and influence developed by the colonial powers of the eighteenth and nineteenth centuries are at the same time inaccessible and unacceptable.

If our national policy is, rather, the avoidance of war than a fatalistic preparation for war, if it means more to us to be harmoniously associated with the great new movements of the world's peoples, then we must labor to find, by the side of the equation between skill and force, a further well-supported and generous equivalence between skill and the ability of our best minds to think and work constructively in a critical world.

It is not a shortage of engineers or atomic physicists that explains the bankruptcy of our China policy. If we have disastrously erred in the Far East, it is partly because American society had so few experts on China to whom it could turn for knowledge and counsel. Even of these few only a pitiful fraction was competent in knowledge or wise in counsel. At this moment we can only guess at the other disasters which ignorance and inexpertness are preparing for us.

No matter where we stand in this issue it is entirely clear that quality must make good our insufficiency in numbers and that we cannot afford to allow any important part of our potential skills to be undeveloped. The security and welfare of the many depend on the skill and training of the few. Therefore our small pool of talent must receive special consideration. Obviously needed in the first place is a fresh examination of the draft upon skilled manpower. Education itself has by far the greatest power to elevate the level of talent. Somewhere in the combined eight years of high school and the undergraduate college there is the most serious loss of time, talent, and energy. Almost certainly an entire year could be salvaged in the case of the brightest students. In fact, the equivalent of two semesters out of the four college years are absorbed by ROTC programs. It has been estimated that almost one half of the 1951 eighteen-year-old group who stood in the top quarter in ability did not go to college. If but a third or a quarter or a fifth of the alert minds that somehow fail to finish high school, or fail to go from high school to college, could be salvaged, the relief would be important. From these facts one conclusion is inevitable. Education must work toward a revival of the close connection of two generations ago between high school and college. The great complex modern high school system serves a variety of goals. If there is any statesmanship in education we must move closer to the conviction of fifty years ago that a primary function of high schools is training for college and university. The links maintained by admissions offices and departments of education are today insufficient to provide for the discussion and cooperation that are needed. A greater effort must be made to see the entire eight years of high school and college education as a continuum. The rigidities and exclusions inflicted by high school systems upon college, and perhaps in greater degree by college upon high school, must be replaced by a bridge of cooperation and understanding between both. There is no need to enlarge upon the baffling isolationism of high school systems or the hauteur of college faculties. One of the most rewarding fields for founda-

tion enterprise would be in this wasteland between high school and college, this limbo in which linger the immature talents of so many young people.

We in the colleges are not in a good position to lay blame on the high schools, for we cannot claim that in admissions and counseling, in the curriculum and the use of student time, we show a full appreciation of the critical bearing of higher education upon a national manpower policy.

It is probably true that we lack the wisdom and courage to revise our ungenerous immigration policy. The effect of an intelligently supervised immigration policy would be meaningful. Skill comes at bargain rates on Ellis Island.

It had better be understood we have no great new reserves upon which we can draw beyond this point. The minority groups and other underprivileged or underemployed sections of the community can bring some relief. Those who, like myself, believed and hoped that women still provide a large untapped reservoir will be disappointed to learn that this may not be true. A number of responsible studies suggest that, alongside a natural preoccupation with family life, there seems to be a lower intensity of ambition among women and a lesser willingness to accept the strenuousness of the higher positions of responsibility and effort which set limits upon the share of women in the present emergency. What has been called the secondariness of women is a condition most difficult to analyze and explain. The difficulty in American society of obtaining favorable adjustment in the body of assumptions and pressures which govern the place of women in society is too great to be handled in this discussion. An atomic bomb on Hollywood and Tin Pan Alley would help.

In the final analysis there is no substitute for the qualitative development of our best brains. Our foreign and military policy has no better ally than the educational system. In any assessment of American power, higher education has the same stature as our system of food production, our industrial organization, or our system of defense. Yet education at all times has greater difficulty in presenting its case than any other essential activity. It is easier to assign a portion of our income to digging oil wells than to stimulating a greater flow of our underdeveloped intellectual resources. The deterioration in the past decade in the financial condition of the colleges seriously limits their ability to make the most effective contribution in "upgrading" American manpower. Lack of adequate financial resources means too few scholarships for able but impecunious students. Often it mea understaffed faculties. Far too often it results stifling academic enterprise that is necessary train specialists in new fields. A number perha as great as 150,000 young men and women a ye is condemned to a lower level of attainment a skill because of the indigence of higher educati

Those who are the greatest consumers of hig level skills have up to the present been little mov by the national damage caused by the insufficie financing of higher education. With exceptio that are encouraging, the industrial leadership America has been deficient in recognizing the ro of higher education in maintaing the flow of skil on which progress depends. True statesmanshi would cause industrial management to encourag universities by whatever means are in their pow to support the indispensable tasks of recruitmen training, and placement which they perform.

A special comment is necessary on the gross ar damaging error of those men who refuse their r terial and moral support to the total life of ou universities because of disagreements with politi cal and economic views held by individual schol ars. Admittedly, faculties have not always bee wise or tolerant in understanding the anxiety from which the modern generation suffers. Academic freedom only sometimes leads to wisdom, and never to infallibility. But the errors of such as these are trifling in comparison with those who expose to ridicule the life of scholarship and who inflict an undiscriminating punishment upon all for the sin of a very, very few. The time has come for universities to speak out in clear anger against the continuing sabotage of intellectual enterprise. Without a wide area of free intellectual activity the ideal of a quality manpower cannot be attained. Those who hurl their loose charges of subversiveness against higher education must be told that they are endangering the activities which have made America the center of medical education in the world, which provide the stream of scientists and technologists without whom industry would sag and collapse, and which, above all else, have through the generations clarified and maintained the ideas and practices of a living and successful democracy. To those who accuse the colleges of being centers of subversion let the answer be courteous but emphatic. American colleges are not centers of peculation and corruption because some of their graduates enter politics and plunder the public purse. In this country it is the marvel and the triumph of higher education that

so few of its teachers and graduates have been clearly and basely faithless to their society. To those who plan to "investigate" the colleges it should be explained that there is no activity more blameworthy than to torture the dignity and destroy the confidence of those who think and write and teach. This explanation must be made for several important reasons. The highest function of education is to make human experience contemporary; that is, to make it available for use in the life of a man or a nation. Yet a great body of scholarship remains antiquarian, and many scholars withdraw into a grammarian's funk hole, because this is safer than to deal with the great issues of the age. As a result society is the poorer for want of the wisdom and the understanding that can only come from scholarship. At this point a very ancient piece of human experience must be made contemporary. The anger and the disaffection of the intellectual, once aroused, are a sword against which neither the purse of the rich nor the law of the mighty can ultimately prevail. A great society never declines but the signs are first plain in either the indifference or the hostility of its intellectuals. When frustrated men crucify scholars for not giving correct or pleasing answers to some of the most difficult problems of all history, then our voices must be raised in defense of the learning and patience, the conscience, and the love of man which characterize scholarship at its best.

There are orders of skill and expertness to which no ordinary measures apply. They are beyond the reach of specific training and scholarly method. Wisdom is the power of seeing things as they really are, and of counseling men to choose those actions which increase the total of peace and justice and charity in the world. Genius is the quality of the special spirit, whether in poetry or politics or science, which raises a man above a single locality or nation to influence the people of the world. To wisdom or genius we can assign no price that any purse can pay. Nor can we devise any curriculum guaranteed to produce them. All we know is that they are likely to arise in an atmosphere where thought and learning are held in honor.

A national policy, whatever its form or emphasis, cannot be successful without the understanding and consent of the people. This is particularly true in a prolonged and restless period of crisis. By far the outstanding phenomenon in the recent Presidential election was anxiety—anxiety about war, anxiety about inflation and high taxes, anxiety about corruption and treason, anxiety about Washington's stunted and disorderly silhouette, anxiety of parents about their sons, anxiety of young people about the future. To the extent that anxiety breeds withdrawal, slackens the will or corrodes confidence, the election revealed that Americans are uncomfortable and unsure in their postwar environment. It suggests that we have not yet done well enough in educating the American people in a knowledge of the turbulent world into which they have been thrown, that we have not done well enough in presenting the national interest as superior to the special interests of the diverse components of the nation, that we have not done well enough in convincing them that, in the proportions of today, Americans are a minority group, which can maintain itself most surely by making quality a rule of life. This quality goes beyond skill and training, though these are vital. There is a list of qualities which men in more religious days evoked with familiar approval, but some of which have grown pale in a more materialistic and incoherent age. They are the recognition that the soul and greatness of a nation are the people's trust, and that there can be a sacredness about being a nation if its policies are guided by charity as St. Paul meant it. They are the knowledge that work is not man's punishment, but the source of his power and achievement. They are, once again, the sanctity of human life and the persuasion that the improvement of the conditions of human life is our greatest new frontier.

The entire debate on skill and training is incomplete unless we see that Pestalozzi's trinity of hand, mind, and heart is indispensable to a manpower policy that stresses quality. A brilliant and sufficient cadre of engineers is surely less effective if New York's waterfront is ruled by brigands. A high level of training in economics is less meaningful if labor and industrial leaders cannot learn the lesson that, although the whole is never healthier than its parts, it is always greater. A stockpile of atomic bombs has less power if sections of the population are blocked by prejudice or made stagnant through ignorance. Health and long life multiply the effectiveness of the body. In the same manner a desire to work and work well multiplies the skill of mind and hand. A national atmosphere of consent and congeniality multiplies the willingness to produce and to cooperate.

The greatest skills we need are not in science or engineering, but in human relations. When I say this I am thereby asking that the opportunity be not reduced for history or philosophy or literature

to speculate upon human relations. Skill in the conduct of human relations is being slowly born and cannot be hastened. It cannot be bought with two billion dollars, or achieved by setting up a Los Alamos of the social sciences and the humanities. But if we do not defend the thought that deals with human life and its values, we may have to study the atomic bomb through our tears before we learn what these values are—that a man or a people has the right to stand in a dignified relationship to others, that the death and suffering of human beings in Uganda or China or Peru must cause sorrow in Chicago or Rome or Tokyo, that in today's world consent and congeniality are as greatly superior to coercion and conflict as was the sense of human community of the New Testament over the tribalism of the Old. Unless these are also goals for our skill and training, then for what are we asking our sons and daughters to live and perhaps to die?

The highest possible correlation between talent and national welfare is imperative. This is true whether we think narrowly and desperately of the power and skill needed for war, of the grim competition in which we are engaged for approval in the eyes of the world, or more nobly of man's task of making the future his everlasting frontier.

Lotus-eaters in a hungry world we have never been. The "blight and famine" of today's world, its "clanging fights and flaming towns" are not to us "a tale of little meaning." We recognize that their pestilence is our pestilence, as their peace must be our peace. The powers that attended the creation of the earth hover over us again. Whether they have come to destroy or to create is the answer we seek.

TWO VIEWS FOR A PARALLAX

Searchers-of-the-heavens,
Measuring for stellar distance
From the dome-capped hills,
Sight to Alpha Centauri, and again
Turn to that fiery splendor
When the earth
Has moved halfway around its revolution
Of the sun.

How all impossible
From one view only
To judge the far projection
Of a world, or thought!
From this one garden I might scan
The sky, and cry:
Alpha Centauri is
A little light, eclipsed
By those high plume-tips
Of the deodars!
But with two different views
For this observing,
Two separate eyes for seeing,
We obtain a rounded
Three-dimensional perspective
Of man-centered patterns,
And a heliocentric parallax
For stars.

GEMMA D'AURIA

Hollywood, California

Herodotus on Biology

L. P. COONEN

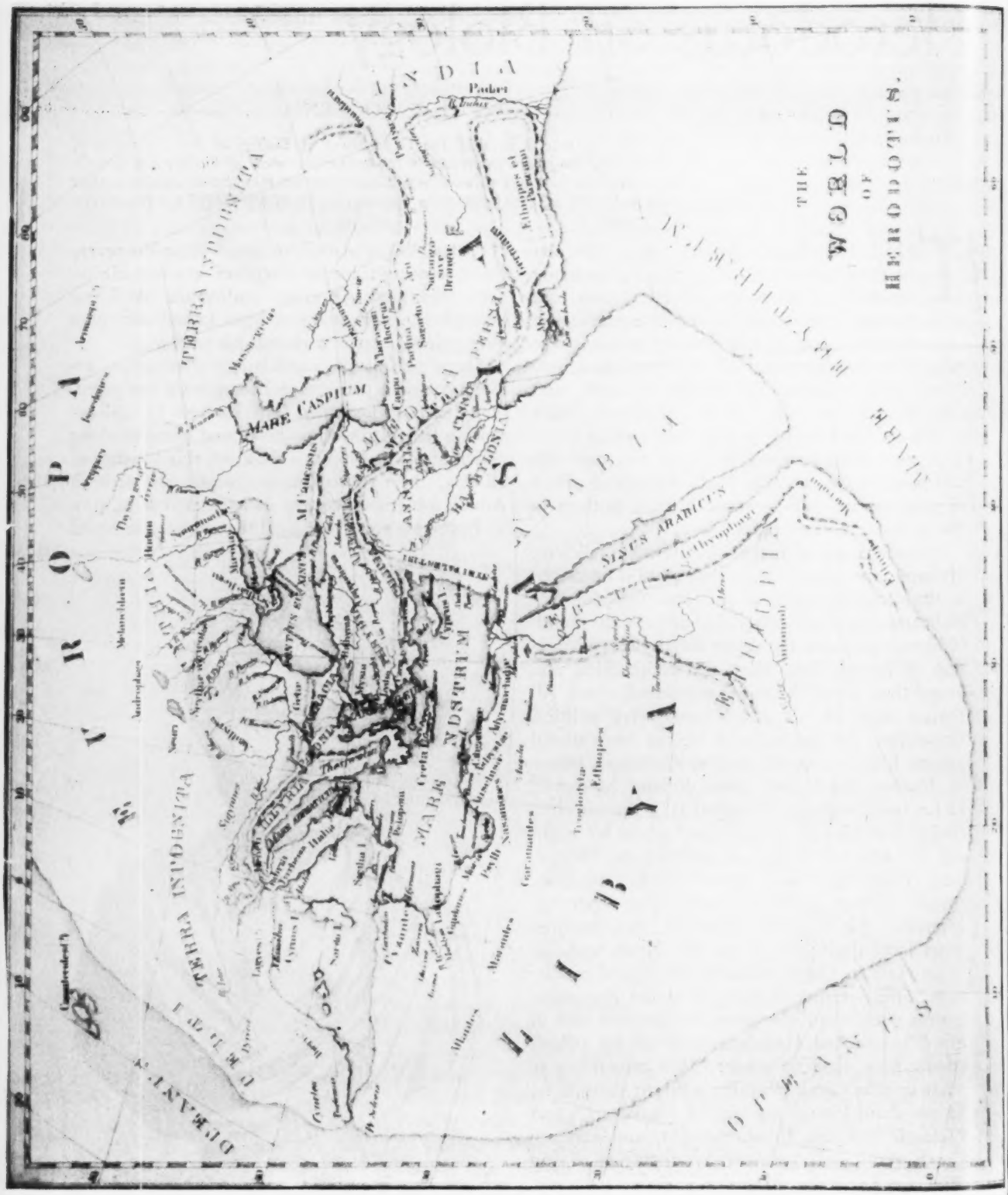
Dr. Coonen, who is head of the Department of Biology at the University of Detroit, has long been interested in the prehistoric roots of biology and is writing a book on biology's obscure beginnings. Two chapters based on this project were published in THE SCIENTIFIC MONTHLY (**73**, *154* [*1951*]; **74**, *211* [*1952*]).

THAT Herodotus (Fig. 1) was a liar has been said often and vehemently by too many historians. The chorus of defamation rose to a deafening crescendo in the late nineteenth century when many of the classical writers were stripped of their glory and left in defenseless shame. Pliny, Strabo, Galen, Thucydides, Plutarch, and even Aristotle, were in turn, or collectively, taken to task for the errors they had passed along to us. The usual procedure was to ferret out, dust off, and point to the mistakes of the long-dead pillars of wisdom and then to castigate their authors in the light of modern standards.

Probably none of these ancients was malicious. Perhaps none was particularly careless if examined in the flickering lights of his time. Herodotus of Halicarnassus fared especially badly at the hands of historiographers. He enjoys the negative distinction of having been chastened more often and longer than any of the others mentioned above. Although most of his denunciators were political chroniclers, the historians of biology have sinned against him in another, a more diabolical, way—by blanket elision and silent disdain. Moreover, he has been intellectually sniped at by the martyred confreres of his own communion,[1] whom we might call the Ancient Targets of Malediction. Thucydides, compatriot and contemporary historian, derided Herodotus for his spectacular reporting; Manetho, the Egyptian historian, two hundred years later dealt him a few low blows with his stylus; Lucian, Greek satirist of the second century A. D., openly criticized him; Pliny the Naturalist, with a giant wind instrument on his own coat of arms, besmirched Herodotus and all his fellow-countrymen when he wrote: "It is astounding to what lengths Greek credulity will go; there is no lie so shameless as to lack a supporter;" and Plutarch, the biographer, moralist, and brother-Greek who is often considered a distinguished and pre-eminent member of several ancient liars' clubs, paid him a unique but oblique honor by composing "On the Malignity of Herodotus." Even the seventeenth century's acerbic Voltaire[2] splashed ink on this celebrated Grecian gentleman. And so, through the ages, tongues have lashed and pens have pricked at the man and his works.

There was some justification. Herodotus, remember, was a pioneer, and there were few precedents in historiography. The road to factual reporting was filled with potholes, and he raced along oblivious of the bumps. Of course, this "Father of History," who recited his spectacular chronicle in Athens sometime between 446 and 430 B. C., promulgated no great biological theory; he discovered

FIG. 1. Herodotus. (From Rawlinson.)


THE WORLD OF HERODOTUS.
EUROPA
ASIA
LIBYA
INDIA
MARE CASPIUM
MARE ERYTHRAEUM
ARABIA
SINUS ARABICUS
Aethiopia
Meroe
Nubia
Memphis
Babylon
Susa
Persepolis
Ecbatana
Nineveh
Sardis
Ephesus
Troja
Athenae
Sparta
Corinthus
Thebae
Delphi
Olympia
Syracusae
Carthago
Gades
Tyrus
Sidon
Jerusalem
Damascus
Petra
Gaza
Alexandria
Cyrene
Meroe
Aethiopia
Arabia
India
Persia
Media
Assyria
Babylonia
Armenia
Cappadocia
Lydia
Ionia
Phrygia
Thracia
Macedonia
Scythia
Sarmatia
Germania
Gallia
Britannia
Hibernia
Italia
Sicilia
Sardinia
Corsica
Hispania
Mauritania
Numidia
Africa
Aegyptus
Creta
Rhodus
Cyprus
Mare Mediterraneum
Mare Rubrum
Mare Caspium
Mare Atlanticum
Oceanus Indicus
Oceanus Septentrionalis
Oceanus Atlanticus
Oceanus Meridionalis
Oceanus Occidentalis
Oceanus Orientalis

no important law; he recorded no shining gems of minute observation. But biology did not begin in that fashion. In its peculiar origin he was a force. Herodotus was one of the early collectors of the nondescript, amorphous body of scattered, unclassified items. Theories, detailed descriptions, and laws came with biology's adolescence, not its infancy. And Herodotus, although not a biologist, should be identified with the incipience of the science because he charted some of the feeble creeks that later were to flow into the streams and torrents and broad rivers, eventually into the ocean, of life sciences.

Herodotus was a restless traveler when traveling was a hardship and an adventure. He was an omnivorous reader when writings were scattered and in diverse tongues. His source materials were gathered, many of them on foot, from dozens of countries and over a latitude of thousands of miles (Fig. 2). He was a historian virtually without a bibliography; he was a research writer without a library; he wrote, before archaeology was born, on happenings remote in time. He was unilingual,[3] but he ran headlong into a babel of languages. He was a tireless writer, when writing was a servile task for the patient and the energetic. But, above all, he was a listener. This was both good and bad for him and his works. We can epitomize him in the vernacular: he had a big mouth, but he had ears to match.

Just as we must absolve Homer, Virgil, and Ovid for vagaries in science and telescoping in history, because these men were primarily poets, we must excuse Herodotus; he was a literary man, a moralist, and a reporter, and perhaps only secondarily a historian. In no wise was he a scientist.

Much of what he heard and reported must have caused him some mental indigestion, for he often set it down in writing with an expressed reluctance. On many occasions we find his interjections of embarrassment: ". . . the Libyans say, I do but repeat their words" (IV, 173); ". . . I only repeat what is said by the Libyans" (IV, 187); "If this be true, I know not; I but write what is said" (IV, 195); ". . . my duty is to report all that is said. . . . I am not obliged to believe it all . . ." (VII, 152); ". . . and some people will perhaps believe them, though I for my part do not . . ." (V, 86); and ". . . to me it seems quite unworthy of belief . . ." (VIII, 119).

From our armchairs, however, it seems that Herodotus misplaced or omitted several apologies. Some are associated with statements since proved true; other declarations, of the wildest variety, were not mitigated either by prefixed partitives or suffixed doubts. Because his curiosity worked like a vacuum cleaner and because he had the interest and ability to describe peoples and customs, his history of the Persian wars is a unique and interesting reservoir of information containing some molecules of biology that might be examined with profit and amusement.

Animals

Herodotus' reportings of animal lore have been of interest to writers in all ages and have often been copied. His story of the crocodile is an example. It has no tongue, said Herodotus; actually, the tongue is small. It eats nothing during the four-month winter, he continued, approaching the truth; the crocodile eats little in winter. He said further that it cannot articulate its lower jaw and that it is blind under water—wrong in both cases. But the great Aristotle apparently borrowed these errors[4] and left his reputation open to many a pot shot because of them. The hippopotamus, too, was a trap for the imaginative writing of Herodotus: he was wrong about the cloven hooves (it has toes), the size (he made it too small), the mane and tail (not like those of the horse). Again, Aristotle seems to have inherited the error of size:[1] no larger than an ass, he said, much later.

On another occasion Herodotus recorded the spectacular and was quite correct. The bulky tails of two kinds of Arabian sheep excited in him an admiration that is reflected in his description of them. One type of tail, he said, is so long and heavy that it is supported and protected by a wooden truck. Similar protective devices are employed today. His digression into the osteology of the camel brought forth some anatomical confusion, for he allocated four thigh bones and four knees to the hind legs. The camel's long metatarsals are partially responsible for this error.

His description of the appearance and habits of Egypt's sacred bird, the ibis, is very accurate. However, the mostly white ibis, not the black one, was sacred.[1] Because the ibis was said to give itself an enema,[5] it was identified with the highly en-

FIG. 2. The world map as probably visualized by Herodotus—the various countries and tribes are mentioned in his writings. Some of the tribal names suggest certain biological problems: Icthyophagi (fish-eaters); Androphagi (cannibals); Lotophagi (lotus-eaters); Bosporus (cow-crossing or ox ford). Herodotus visited the general areas immediately surrounding the Mediterranean Sea, shown in the approximate center of the map, and he reported legends, true or fanciful, about the other regions. (From Rawlinson.)

dorsed medical practice of frequent purgations. Hence the bird was considered very gifted, and even god-linked. This protected fowl was a nuisance in the streets of Alexandria[6] and certainly a sartorial hazard. All this special attention probably underwrote the accuracy of its description.

The phoenix, an ancient ornithologist's dream (Fig. 3), was likewise carefully described by Herodotus, but he admitted that he had never seen one. The Syrian philosopher Porphyry[1] says that Herodotus filched this description from his Greek predecessor Hecataeus. This myth-on-wings was supposed to have a life span of 500 years in Egypt; then it returned to Arabia to be voluntarily consumed in fire. Its life cycle began anew when it rose fresh and frisky from its own ashes.

Otters and leeches are described as occurring in the Nile, but according to How and Wells[1] neither animal is found there. Snakes were the subject of various comments and observations. He reported winged snakes in Arabia, and "little snakes, each with a single horn," in Libya. The latter could well have been the smooth, three-inch caterpillars of one or more of the hawk moths. And, as an accurate item of herpetological observation or reporting, he noted in general that some snakes are oviparous, and others ovoviviparous.

Herodotus' story of fish fertilization is less acceptable. During the spawning season females follow the males, he wrote, and swallow the sperm. Fertilization somehow resulted. Aristotle saw the fault here, corrected (in his *Generation of Animals*) his predecessor, quoted his misstatement, mentioned his name;[7] and fixed the record for all time.

That the oxen of Scythia have no horns may be true, but when Herodotus attributed the polled feature to the low temperature he admitted that he leaned upon Homer (*Odyssey*, IV, 85) to support his contention.

On occasions, such as in Book IV (191–192), where he listed the fauna of Libya, our ancient author rattled off long lists of animals. We learn of huge serpents, but not so large as those reported by Pliny, who called the Greeks liars. The Roman reported in his *Natural History* (Vol. VIII, 37) that a certain 120-foot serpent skin was brought to Rome! Herodotus listed other Libyan animals: lions, elephants, bears, asps, horned asses (a kind of antelope?), antelopes, gazelles, buffaloes, asses ("not of the horned sort"), oryxes, foxes, hyenas, porcupines, wild rams, dictyes, jackals, panthers, boryes, "land-crocodiles," two-legged mice (jerboas, with reduced front legs), another mouse called "zegeries," and "prickly mice." The commentaries on Herodotus[1, 2] identify most of these, but not all.

Insects, too, received some attention. This extensive traveler, often enduring primitive transportation and shelter, met many of them in his reluctant passivity. He reported that the mosquitoes were so bad that the Thracians could not inhabit certain areas of their country. And the gnats of Egypt forced the citizens to build high towers to get above them.

The best entomological tale is the much-repeated story of the gold-digging ants of India. Swift's Gulliver could not outdo this whopper, probably first "reported" by Herodotus (Book III, 102, 105). In size, he said, they were ". . . less than dogs, but bigger than foxes." They burrow underground, throwing up sand which "is full of gold." The ants "are so swift . . . there is nothing in the world like them." The tale picked up momentum and inflation as it was mouthed by historians and "witnesses."[1] Nearchus, Alexander's admiral, "had seen" the skins of the "gold-digging ants," which are "like those of panthers;" Strabo embellished the story from several sources; Megasthenes described the plain that the ants inhabited. Prester John's imagination, in the twelfth century, equipped the beasties with seven legs and four wings; the sixteenth-century Flemish traveler de Busbecq related that the Persian ambassador presented an Indian ant, "*magnitudine canis mediocris, animal mordax et saevum,*" to the Sultan of Constantinople. Because this giant hymenopteran was "biting and raging" the scene is realistic. *Somebody* "saw" it, but Herodotus seems to have been the grandfather of that vision.

One tantalizing sentence in Book IV suggests an early application of an endocrinological principle, but not an understanding of it. In describing the customs of a tribe which he called the Budini, Herodotus wrote that the people catch an ". . . animal which has a square face . . . and whose testicles provide a remedy for diseases of the womb."[3]

A few furrows were ploughed in the virgin field of organic evolution. Of course, Herodotus envisioned little of the great panorama of evidence that was to be placed on parade twenty centuries later, but he dwelt upon some of the concepts that were later to be identified with the names of Malthus and Darwin. Even though his examples were weak, he strained to demonstrate and support his theory that the survival of species of defenseless animals is maintained by their accelerated reproduction. Although parthenogenesis and "encapsulation" actually exist in certain rotifers and

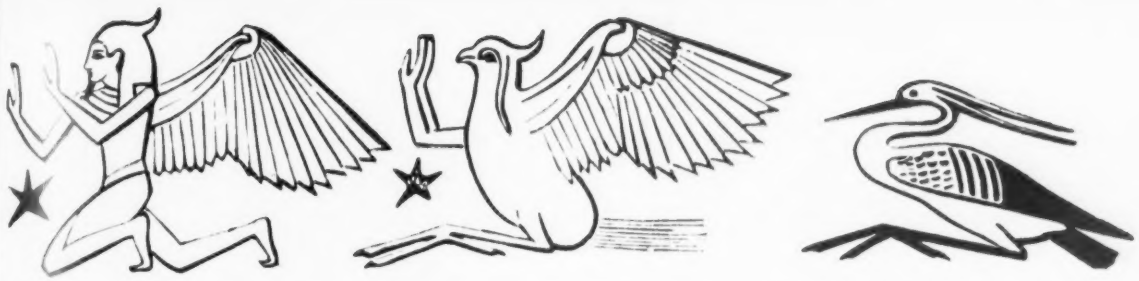


FIG. 3. Variations of the phoenix, mythical bird, admittedly not seen by Herodotus, but reported by him. After a life span of 500 years (or more) in Egypt, it reputedly returned to Arabia and voluntarily flew into fire; then from its own ashes it arose to begin another 500-year cycle. The figures middle and left, appearing on ancient monuments, are sometimes believed to represent the phoenix; the one at the right certainly represents it. (From Rawlinson's woodcuts.)

aphids, Herodotus conveniently devised something akin to it in the hare. He stated that there may be four litters in different stages of development at one and the same time in a hare's uterus. Further to fortify his claims, he used an antipodal and equally false situation. The ferocious lioness has, according to this author, only one gestation in a lifetime. He further developed this thesis by stating that but one cub is born, and that the mother's womb is hopelessly clawed and lost during the delivery of it. That, he implied, is nature's way of keeping this predaceous animal numerically in its place. One more example was evoked to demonstrate population control. This time he chose the fanciful "winged serpents of Arabia." The males, he said, are disposed of by the females during mating; the females are likewise destroyed when the young ones eat their way through the maternal body wall at the time of birth.

Plants

Many references to botanical items are interposed, often casually. Rarely do Herodotus' words attempt to elicit mental pictures of the organisms. An exception is his description of Egypt's lotus which, though sketchy, clearly indicates *Nymphaea lotus*, the "white-flowered lotus of Egypt."

Herodotus made only desultory references to plant morphology, and it would seem that his interest in herbs and trees was colored by his concern for commerce and economics. In fact, a standard commentary[1] suggested that Herodotus may have been a traveling merchant. For instance, his stylus lingered over, not the size and symmetry of the castor plant, but the virtues of castor oil. He underscored its uses as an unction and a lamp fuel. Nor were his references to the papyrus plant concerned with its morphology and anatomy. He elaborated upon its importance in the Egyptian economy: for writing materials, ship sails, and even food. Plants and animals as dietary items are often referred to. Fermentation was already an old and commonly utilized process in his native Greece. So he casually referred to wine and beer without comment on their manufacture or effect. Straight-faced Aristotle was not so reserved; he interjected a priceless comment into his own writings[1] to the effect that a "man drunk with wine lay on his face, while beer laid him on his back."

The acacia tree evoked no enthusiasm for its form, size or growth habits, but Herodotus described how three-foot acacia planks were overlapped like bricks and fastened in that arrangement to construct the bulkheads of Egyptian vessels. On another occasion he mentioned asphodel (*Asphodeline lutea* Reichb.) and rushes, both of which supplied the slender stems used by the Nesamonians of Libya for building light, portable houses. On still another, he mentioned the use of madder root for dyeing clothing. Substantiation came recently when mummies were found with garb so dyed.[8]

In at least one instance Herodotus used plant ecology to circumscribe a geographical entity: "Weasels also are found in the *silphium* region" (Fig. 4).* Plants were often mentioned by him only in a cursory way, usually suggesting no interest in the plants themselves—e.g., the Persian sacrificer wore myrtle on his turban; and beans were never sown or eaten by Egyptians.

One allegorical statement he made suggests a knowledge of asexual reproduction, or the lack of it in certain trees. Herodotus quoted one of his

* This plant was probably the modern *Ferula tingitana*, a near relative of the wild carrot. *Silphium's* flowering stalk, according to Theophrastus, was eaten boiled or roasted; its root produced a resinous liquid supposedly of great medicinal value.

FIG. 4. Conventional representations of *Silphium* on coins of ancient Cyrene. This plant is not to be confused with the modern genus of the same name. This ancient and important organism was a member of the parsley family, and not of the Compositae, like the modern *Silphium*. This economic plant was so highly valued in Herodotus' time as a vegetable and as a source of a resinous drug (modern gum ammoniac) that it was figured on coins, as are wheat, fish, and grapes in those countries where such commodities are most important. (From woodcuts by Rawlinson.)

historical characters as saying he ". . . would destroy them like a fir," meaning *completely* or *finally*. Many trees send up adventitious shoots from their new stumps. Not so the fir. When cut down, it has no potential for vegetative reproduction.

Sanitation

Herodotus reported some practices and attitudes that suggest a rudimentary code of sanitation among the earliest civilizations. Whether or not his reports are true reflections of the ancient general practice, at least the ideal was stated or implied. He said about the Persians that "they never defile a river with the secretions of the body, nor even wash their hands in one. . . ." Another time, in reference to the habits of Cyrus, he noted that the great Persian, on a military campaign, carried a water supply with him "ready boiled for use, and stored in flagons of silver. . . ."

Meat inspection seems to have been a religious rite among the Egyptians, as it is today among the Hebrews. Regardless of the final expression of the precautionary measures resorted to, the underlying fact remains that the ancient Egyptians, in a land which is today below average in its practices of sanitation, did inspect the carcasses of slaughtered food animals. Herodotus recorded that the priests first made an external inspection; then they examined the tongue and the mouth. If the animal was free of certain telltale signs of parasitic infection, it was officially approved by branding a horn (if it possessed horns).

According to this Greek writer, the Egyptian priests were paragons of personal purity in their daily habits. They scoured their brazen cups every day and wore freshly laundered linen clothes. What is more, they shaved "their whole body every other day . . ." and bathed "twice every day in cold water, and twice each night." Although circumcision may have become involved in the niceities of religious ritual, Herodotus wrote straightforwardly that the Egyptians practiced it "for the sake of cleanliness."

Medicine

Human curiosity is whetted easily and keenly by anthropocentric ideas. Medicine is the most attractive of those ideas because health and personal preservation are natural and selfish concerns. Herodotus looked long and listened well when he confronted the healing arts, but the very setup of medical practice mitigated against him. It was a closed union. No amount of snooping by an outsider would disclose the carefully guarded secrets of the art. This was especially true in Egypt, where contemporary medicine was a chaotic admixture of astrology and mysticism. The great medical papyri, some of which had been written ten centuries before the time of Herodotus, were moldering in unknown tombs, not to be discovered for another 2300 years. He said, however, of contemporary medicine in the land of the Nile:

> Phisicke is so studyed and practysed with them that every disease hath his severall phisition, who stryveth to excell in healing that one disease, and not to be expert in curinge many: whereof it commeth that every corner is full of Physitions. Some for the eyes, some for the head, many for the teeth, not a fewe for the stomacke and

belly. Finally, such as are of knowledge to deale with secret and privy infirmities.[9]

And he stated in very general terms how he saw medicine practiced in Babylonia. Again, we must note that his vantage point was peripheral and his view contemporary. He leaves the impression that there were no physicians in Babylon. The lame and the diseased were transported to the public square, there to meet the merchants and shoppers who happened by. Recipes were traded, illnesses were compared, fertile imaginations sprung wild ideas, foggy formulas were pumped forth from stagnant memories. This clearinghouse was at once medical school, hospital, and physician in Herodotus' day.

With appropriate skepticism, the Great Reporter recorded a strange medical procedure of the Libyans. Four-year-old children had the veins of their temples or scalps burned "to prevent them from being plagued in their after lives by a flow of rheum from the head." If the drastic treatment brought on convulsions, the practitioners resorted to a standard treatment: they sprinkled "goat's urine upon the child, who . . . is sure to recover."

Without comment or attempted explanation, he reported a case of battle hysteria: "Epizelus . . . was in the thick of the fray, and behaving himself as a brave man should, when suddenly he was stricken with blindness, without blow of sword or dart, and this blindness continued thenceforth during the whole of his after life."

He also reported what seems to have been a double case of psychosomatic effect on childbearing in the royal Spartan household. Wife Number One, in her anxiety to conceive, was barren; Wife Number Two, acquired by special legislation, quickly produced a child. Wife One, released of her sole responsibility to conceive, produced three sons in rapid succession; Wife Two, in her chagrin at losing favor, never conceived again.

Embalming

Of all the accomplishments of the ancient Egyptians none has aroused more wonder and acclaim than their embalming practices. The best proofs of their success are the Egyptian mummies now to be found in all major museums, and evidently many bodies remain to be uncovered. Rawlinson[10] estimated that when embalming ceased in Egypt, about 1200 years ago, 420,000,000 mummies had been prepared. The number has been placed as high as 730,000,000.[11]

Most of the museum pieces were recovered twenty centuries after the death of Herodotus. What he wrote about the details of embalming in Egypt is borne out by careful examination of the mummies—for example, the skulls are empty, and there is a hole bored from the nostrils to the brain cavity, just as he described. Listen to his account of three methods of embalming (there were probably more[1]):

> The mode of embalming, according to the most perfect process, is the following: They take first a crooked piece of iron, and with it draw out the brain through the nostrils, thus getting rid of a portion, while the skull is cleared of the rest by rinsing with drugs; next they make a cut along the flank with a sharp Ethiopian stone, and take out the whole contents of the abdomen, which they then cleanse, washing it thoroughly with palm-wine, and again frequently with an infusion of pounded aromatics. After this they fill the cavity with the purest bruised myrrh, with cassia, and every other sort of spicery except frankincense, and sew up the opening. Then the body is placed in natrum for seventy days, and covered entirely over. After the expiration of that space of time, which must not be exceeded, the body is washed, and wrapped round, from head to foot, with bandages of fine linen cloth, smeared over with gum, which is used generally by the Egyptians in place of glue, and in this state it is given back to the relations, who enclose it in a wooden case which they have had made for the purpose, shaped into the figure of a man. Then fastening the case, they place it in a sepulchral chamber, upright against the wall. Such is the most costly way of embalming the dead.
>
> If persons wish to avoid expense, and choose the second process, the following is the method pursued: Syringes are filled with oil made from the cedar-tree, which is then, without any incision or disembowelling, injected into the bowel. The passage is stopped, and the body laid in natrum the prescribed number of days. At the end of the time the cedar-oil is allowed to make its escape; and such is its power that it brings with it the whole stomach and intestines in a liquid state. The natrum meanwhile has dissolved the flesh, and so nothing is left on the dead body but the skin and the bones. It is returned in this condition to the relatives, without any further trouble being bestowed upon it.
>
> The third method of embalming, which is practiced in the case of the poorer classes, is to clear out the intestines with purge, and let the body lie in natrum the seventy days, after which it is at once given to those who come to fetch it away.

He wrote that cats and dogs were also accorded this kind of desiccated immortality and buried in sacred places. Such feline and canine cemeteries have been excavated,[1] again substantiating a point for the Great Reporter.

Without comment, and perhaps without confirmation by posterity, Herodotus noted that the Persians covered the bodies of their dead with wax before burial, and that the Assyrians used honey as an enduring preservative.

Anthropology

If we properly consider Herodotus as a general narrator, and not as an anthropologist, we can

better appreciate some of his musings on the subject of the races of mankind. He claimed that the dark-skinned peoples of India and Ethiopia produce black semen. For this he was rebuked by Aristotle in the *History of Animals* and again in the *Generation of Animals*. The great philosopher chided Herodotus with an analogy: Are not the teeth of the Negro white?

More cautiously, Herodotus referred to the one-eyed Arimaspi of the far northern regions of Europe and Asia, who "purloin gold from griffins." He doubted the existence of this one-eyed race; then, nursing his doubt, he philosophized that the remotest parts of the earth produce "just the things we think most fair and most rare."

He seems to have relished his reporter's role when he stated that in a certain tribe both male and female members were bald "even from birth." Although this is a hereditary and anthropological possibility, such an exotic and conspicuous group would have been noted by other travelers, as it was not. He probably was careless in noting the presence of a religious or ceremonial tonsure, or some other form of acquired "baldness."

His writings teem with references to anthropological criteria. He described a new race of people by noting that their appearance or dress might be similar to one previously discussed, but that their other customs were quite dissimilar. Sometimes his apparent ecstasy unleashed his vagrant imagination, as when he stated that Ethiopians were the tallest, most handsome, and longest-lived men in the world.

He recorded, perhaps for the first time, a description of a certain Paeonian people who were lake dwellers. Their homes were supported by piles driven into the lake bottom. A mountain of evidence gathered in the past two centuries has verified the custom as having been a widespread one in Neolithic and early historical times.

Bizarre osteological finds were reported by Herodotus: a skull without sutures; and upper and lower jaws in another case, each one possessing a single continuous, laterally fused complement of teeth, "made entirely of a single bone." Curiously, Pliny also described the fusion tooth (Bk. VII), and Plutarch noted this condition in young Pyrrhus, a Grecian king. Probably all were inaccurate.

Herodotus had, and still has, some faithful admirers. Aristotle frequently borrowed from him, a tribute further enhanced by the seven times Aristotle mentioned his name. Pliny often quoted him and his data. Sophocles penned a poem to him. And a modern medical historian, Robinson,[4] generously declares "modern scholarship confirms his trustworthiness." Another, the historian of science Dampier,[12] praises him for "his laudable curiosity" and his "valuable description of peoples." How and Wells[1] toss him two well-chosen flowers: he is "never dull" and he is a "great storyteller."

Biologist or no, he unwittingly wrote a neat and appropriate epitome of himself and his work in the first sentence of his famous history: "Herodotus beyng of the citye of Halicarnassus in Greece wrote and compiled an history to the end, that nether tract or time might overwhelme and bury in silence the actes of humayne kynd: nor the worthye . . . might want the due reward of immortal fame."[9]

References

1. How, W. W., and Wells, J. *A Commentary on Herodotus*, 2 vols. London: Frowde (1912).
2. Cooley, W. D. *Larcher's Notes on Herodotus*, 2 vols. London: Whittaker (1844).
3. *Herodotus—The Persian Wars* (trans. by G. Rawlinson). New York: Random House (1942).
4. Robinson, V. *The Story of Medicine*. New York: New Home (1943).
5. Hoffman, R. H. *The Struggle for Health*. New York: Liveright (1929).
6. *The Geography of Strabo* (trans. by H. L. Jones), 8 vols. New York: Putnam (1917).
7. *The Works of Aristotle Translated into English*. Vol. 5, *de Generatione Animalium* (trans. by Arthur Platt). Oxford: Clarendon (1910).
8. Cameron, G. *Ann. Med. History*, **4**, 466 (1932).
9. *The Famous History of Herodotus, Translated into English by B. R. Anno 1584*. New York: Knopf (1924).
10. Rawlinson, G. *History of Ancient Egypt*, 2 vols. New York: Dodd, Mead (1880).
11. *Encyclopedia Americana*. Article on "Embalming," **10**, 273 (1941).
12. Dampier, W. C. *A History of Science*. New York: Macmillan (1943).

Oldest Material: Newest Uses

WILLIAMS HAYNES

In November 1952 The Scientific Monthly *published a short abstract by Mr. Haynes from his forthcoming* American Chemical Industry: A History in Six Volumes (*Van Nostrand*). *His present article is based on Chapter 1 of his new book* Cellulose: The Chemical that Grows, *which is being published by Doubleday & Company on March 5.*

EONS ago, when some lovelorn caveman picked up a stout stick, clouted a pretty cave maiden over the head, and carried her off to his den, civilization started. Man had appropriated a natural object and used it to his own selfish ends. By wielding that club he had become a tool-using animal.

From the very beginning wood has been man's favorite material. His first weapon was a club, his first agricultural implement a crooked branch. Wood was also his first fuel. From planks to toothpicks, even today we fashion wood into more diverse shapes and put it to more different uses than we do any other substance. It is our oldest, our most familiar, our most useful, industrial raw material.

All wood is composed of about half cellulose. Every living thing is made up of minute cells, and the cell walls of all living plants are composed of cellulose. The sturdy oak and stately palm, the grass that covers the good earth, the lichens that clothe the rocks, even the minute algae that flourish in the sea, all are manufacturing cellulose. It is the great primary substance of the whole vegetable kingdom.

Cotton for calico, flax for linen, hemp for rope—our great vegetable fibers—are all composed chiefly of cellulose. Paper is almost pure cellulose. It is made of the fibrous part of wood cleaned of its sap, its resins, its minerals, and its binding compound called lignin, and then felted and pressed into thin sheets between rollers. These are old, everyday uses of cellulose, as commonplace as a handkerchief and this morning's newspaper.

Through chemistry, we have quite recently discovered startling new uses for this, our oldest material. Only a century ago a jolly little bespectacled college professor first combined cellulose with nitric acid and obtained nitrocellulose, the first chemical derivative of the chemical that grows. He never dreamed that he was laying the foundations of four great modern industries. Peering nearsightedly into his porcelain reaction vessel, Dr. Schönbein saw a fluffy white substance. It looked just like the cotton he had used when he began his historic experiment. He soon discovered, however, that this cottonlike substance did not behave like cotton at all. A chemical reaction had taken place. He had a new substance and he found that, for one thing, it exploded.

This cellulose nitrate of Schönbein's had other remarkable chemical properties. He prophesied truly that someday it would replace gunpowder. But he caught no vision of bright-colored plastics or luscious rayons or tough, quick-drying lacquers or transparent wrappings. Yet all these, and other new products too, lay in the future of cellulose once we learned to use it as a chemical raw material.

Today, cellulose treated with chemicals yields not only rayon, plastics, lacquers, and films for wrapping and for photographs and motion pictures, but many other useful products that range from fingernail polish and compounds to relieve stomach ulcers to wallboards and belting to drive machinery. Before we could harvest this rich crop of new products for better living, scores of patient research workers had to learn a lot about cellulose itself. Indeed, they had to probe close to the very innermost chemical secrets of life in order to solve the mysteries of the exceedingly complex cellulose molecule. Then brilliant investigators had to learn bit by bit how to make this stubborn, unreactive material combine with chemicals so as to make the new products to suit our needs. These researches are fascinating chemical detective stories. Their practical consequences to every man, woman, and child in America are staggering.

Motion pictures projected through a cellulose film are as epochal an advance in education and entertainment as was the word printed on paper made of cellulose. Mass production of all sorts of goods, from motorcars to pencils, would pile up in a jam at the end of the assembly line were it not for quick-drying lacquers to protect and decorate

the finished product. By making luxury fabrics available to everyone's pocketbook, rayon has rendered the "silk-stocking class" in America as obsolete as the zinc-lined bathtub. Other chemical offspring of cellulose are, as we shall see, quite as revolutionary characters.

Within the past twenty-five years, thanks to chemical research, man's oldest material has thus become the basis of ultramodern industries. The chemical that grows is now one of our most important, most versatile raw materials, so that today we Americans consume over 85,000,000 tons of cellulose. That is almost as many tons as we use of steel and ten times as much cellulose as we consume of both aluminum and copper.

The purified cellulose we use in industry takes no account of the billions of tons of raw cellulose eaten as fodder by beef cattle, dairy cows, and horses, or the billions more tons that we ourselves consume in carrots and beets, apples and peaches. All grasses, all vegetables, all fruits, contain more or less cellulose.

Fortunate indeed for mankind that this greatest of our raw materials is what the economists call a "replenishable asset." Unlike our great mineral raw materials—coal, petroleum, sulfur, phosphorus, potash, and all the metals—the supply of which is fixed, cellulose is a product of all living plants. It is truly a substance of superabundance in nature. No matter how many new uses we may find —and new uses of cellulose are developing thick and fast—we shall never run short of this raw material. If one source of cellulose becomes seriously depleted (as might conceivably happen) we can use other forms for chemical processing and also for fabricating into wallboard to replace builders' lumber.

Not only is cellulose abundant but, what is most important in these days, it is widely available. Save in the polar regions and the deserts, cellulose is at hand for use by all peoples all over the earth. There is probably no have-not cellulose nation. Cellulose is the great chemurgic crop—that is, a crop grown for industrial use, not for food. The chemical that grows is an ideal raw material out of which to build a global economy of abundance for all mankind.

Nature seems to have arranged this for us most providently and conveniently, for she has set up a neat cellulose cycle. Sheep and cattle digest cellulose, turning it into chops and roasts, which we relish. On the other hand, the cellulose we eat serves only as roughage in our diet, since we cannot digest and assimilate it. A subtle distinction, this, between man and beast, one of tremendous import.

More subtle still is the distinction between cellulose and sugar, two products that are manufactured exclusively by plants. In the chemical elements that make up the complex molecules of cellulose and sugar, the only difference is that of two atoms of hydrogen and one atom of oxygen, H_2O, one molecule, more or less, of water. Although cellulose is quite indigestible in our human stomachs, sugar is easily assimilated and readily turned into fat—too readily, alas, for many of us! This minute distinction of a single molecule of water is another of the thick-veiled chemical mysteries that still surround cellulose.

Reasonably enough, the first processing of cellulose was a simple mechanical fashioning. The Egyptians who made the first paperlike material by pulping papyrus reeds, drying them, and rubbing the surface smooth with a knucklebone wrought no chemical change in the material. From this mechanical pulping and polishing of cellulose, the clever and secretive Chinese took a long forward step when they made true paper by suspending a fibrous mass of cellulosic pulp in water and dexterously depositing it in a thin, even sheet on a wire screen, through which the liquid drained off. They perfected this tricky technique some two centuries before Christ. Not till A.D. 751 at Samarkand was this useful art revealed to the Western world. That fabled city, then the easternmost outpost of the conquering Moslem armies, was attacked by the Chinese, and in following up their repulse, the Arab governor captured several skilled papermakers.

Papermaking soon became quite a business of the Arabs, and it spread throughout the Moslem world. The Moors carried it to Sicily and Spain. Thence it moved on to Italy and France, the Low Countries and Germany, and finally to England. By the fifteenth century paper had replaced vellum and parchment throughout Europe.

Our modern gigantic papermaking machines, from which roll more than 2000 feet of paper a minute, mile after mile, in sheets as much as 24 feet wide, still employ what is essentially a highly mechanized form of the dexterous hand technique of the Chinese. Paper is still a thin tissue composed of any fibrous material whose individual fibers, first separated by mechanical or chemical action, are deposited and felted together on a wire cloth.

The phrase "any fibrous material" opens a door as wide as the breadth of the vegetable kingdom. In different lands papermakers at various times

have used cellulose from many sources, picking always the cheapest and most readily available. The most ancient process of the versatile Chinese was to boil the fibers of the bark of the mulberry tree in a lye made of leached wood ashes. They also employed bamboo pith and, later, after the plant had been imported from India, cotton fibers. Knowing antiquarians can readily identify old manuscripts written on so-called Oriental paper, because it is thick and soft, white, and exceedingly well preserved over the centuries. Paper made by the Arabs is thinner, harsher, and tougher, for it was made of linen.

Whatever the fibrous cellulosic material employed, the problem of the papermaker is always to eliminate the glutinous, resinous, siliceous, and other material found within the cells, always associated with the cellulose of the cell walls of all plants. In Europe papermakers soon discovered that rags furnished the easiest, most economical raw material. The fibers in cloth had already undergone a partial cleansing, and white linen rags were much preferred, for they made the stoutest, whitest paper.

There was then no known method of bleaching dyed rags. Accordingly, even the finest sheets of paper made from hand-picked scraps of fine linen were creamy or grayish. The ordinary grade was distinctly brown, frequently speckled. Nevertheless, quality improved and output increased. So papermakers embarked on the familiar economic sequence: lower price, wider use, greater demand. Their expanding market ran plumb into a barricade: a shortage of rags. Various substitutes were sought. In 1659, when Queen Elizabeth granted a ten-year monopoly in papermaking to her favorite jeweler, Sir John Spilman, it carried exclusive rights to gather not only linen rags but scrolls and scraps of parchment, old fishing nets, cordage, and "any other materials as might be suitable."

After newspapers appeared, the rag shortage became acute. Here was a new use for paper, not to be filed away in official archives or bound in stout calfskin, but a sheet to be scanned and discarded, crumpled under the kindling in the fireplace, or twisted into spills for lighting tallow candles and long clay pipes. Some whimsical economic philosopher may one day enjoy expanding the theme that our first frankly expendable manufactured product was newsprint paper. Be that as it may, the early newspaper editors were not fussy paper buyers. They could not afford to be. They must have paper, lots of paper, cheap paper. So long as it was printable, they did not worry about its appearance or its permanence. Accordingly, papermakers began experimenting with straw and from it they produced the first newsprint. It was pretty poor stuff, off-color and harsh; but it was cheap and in reasonable supply. What distressed the printers was that its hard, rough surface wore down type metal like a file, so that a font of type, previously good for a year's hard service, wore out in three or four months.

About this time both machinery and chemicals appeared suddenly on the papermaking scene. The Industrial Revolution came to paper in 1798 when Louis Robert, clerk in the Essonnes paper mills in France, invented a machine that a London stationer, Henry Fourdrinier, introduced into England. Paper made by machine meant more paper, cheaper paper. The rag shortage became a famine. Discovery of the bleaching action of chlorine saved the papermaking machines. It eked out the pulp supply by bleaching hemp rope and burlap bags. The hemp and jute papers, like those made from straw, were of poor quality. There was still plenty of incentive to find some other cheap, abundant material that would pulp easily and produce a good sheet.

Any cellulosic material can be made into paper. Indeed, a busy French chemist once made a respectable product out of thirty-seven different plants that ranged from artichokes to pine trees. Plainly, it was well worth while for a man to discover a more suitable raw material for the hungry paper mills, so ambitious chemists and adventurous papermakers began hunting. They were granted many patents, but it was a simple hand-weaver of linens in his cottage in Hainichen, Saxony—Gottfried Keller—who in 1840 made the great discovery. Keller had a chum, another cottage craftsman, Heinrich Voelter, a handicraft papermaker who directed his friend to this problem.

Keller first attempted to make paper out of wasps' nests, a tough, water-repellent material that had heretofore (and has since) attracted other investigators. He failed, but one evening while strolling about the village he came upon a group of children intently gathered around a grindstone. One sturdy boy was whirling the crank; the others were taking turns pressing cherry pits against the revolving stone in order to grind in each a tiny hole. It was, in fact, a cooperative enterprise in the manufacture of cherry-pit necklaces. Some smart youngster had discovered that, by half burying the pits firmly in a little depression in a board and then holding them against the whirling stone, the risk of raw and bloody fingers was eliminated.

The revolving stone passed in its lowest circuit through a trough of water upon which floated a thick layer of pulverized wood and cherry stones. Keller scooped up a handful of this woody scum and pressed it to squeeze out the water. It became a pulpy mass which, as he kneaded it between his fingers, reminded him of the rag pulp that Voelter turned into paper. He hurried off to his comrade, and next morning they were at it again, experimenting. Out of those experiments came cheap wood-pulp paper.

The inspired Keller did not become a multimillionaire. He sold his share in the venture for $700 to his friend Voelter, who about 1858 perfected a process for the ground wood pulp. His methods were too easy to copy, so that even he, though he sensed its commercial importance, gathered no suitable reward. Neither realized what he had accomplished. Not only had they broken down the rag-supply barrier, but they had opened up the first great market for cellulose. Furthermore, their ground wood pulp of reconstructed cellulose soon led to chemical treatment of cellulose.

Ever since 1690, when William Rittenhouse, a German papermaker, and William Bradford, an English printer, became partners in the first paper mill in North America, the familiar rag problem had been especially insistent in this country. Rags were always extraordinarily scarce. To make matters worse, the American colonists were avid newspaper readers, a habit that has persisted long after other admirable characteristics of Puritan and Cavalier have vanished.

Inventive Americans tried out all the likely fibrous materials, and Yankee ingenuity came up with some novel suggestions. Patents were granted in 1802 to Burgess Allison and John Coffin for paper from cornhusks, and in 1809 to Samuel Green, the printer of New London, Connecticut, for paper from seaweed. Chlorine bleaching was promptly borrowed from the textile mills by American papermakers. Bleached straw paper began to be made, so that during the early 1850s the price of good rye straw jumped from $6 to $20 per ton. This pleased the Midwest farmers. They had many acres planted to rye to supply the demand of the whiskey distillers, and now they had a pleasant cash bonus in the sale of by-product straw.

Ground wood-pulp paper was made here shortly after 1865. It had defects as obvious as a break in a motion picture film. The cellulose fibers were short, which meant low strength, and the pulp contained the saps, resins, and other substances associated in the wood with cellulose. These were later removed by boiling in soda ash, an idea hit upon by English papermakers, but there was still plenty of room for improvement.

An American made a most notable chemical contribution to papermaking. The innovator was Richard Albert Tilghman, scion of a distinguished family established by Dr. Richard Tilghman, who came with Lord Baltimore's first colonists to the Eastern Shore of Maryland. Of all the soldiers—Colonel Tench Tilghman was General Washington's favorite aide—governors, great lawyers, and many physicians among the Tilghmans, this Richard left a worthy mark. He perfected a process for splitting tallow into fatty acid and glycerin, which revolutionized the soap and candle businesses; he developed the process upon which was founded the famous Baltimore Chrome Works, which made a superior yellow pigment for paints; with his brother he invented the sandblast process of polishing metals and cleaning stone.

We are chiefly indebted to this tall, handsome aristocrat for the sulfite pulp process, which makes a type of paper still in universal use. The principle of his method, though refined in details, is still the basis of the process. Logs, debarked and with the knots removed mechanically, are chipped in a hogging machine to thin slices, which are boiled under pressure with sulfurous acid and lime or magnesia. Tilghman's sulfite process for making fine paper stock, and the English soda process, which treats ground wood pulp with soda ash to produce newsprint, have a younger rival. This sulfate or kraft process produces a tough paper from wood chips, cooked in a mixture of caustic soda and sodium sulfide. This is the industry that since 1935 has blossomed in our Southern states so amazingly that now more than fifty mills are pulping over 4,000,000 cords of wood each year, turning out some 3,000,000 tons of kraft paper and paperboard.

Without the foggiest suspicion of the chemical composition of this curious, complex substance, apt craftsmen of five thousand years ago had found ways to fabricate cellulose. They soaked the stems of flax till the mass fermented, dried them, flayed them with mallets, and picked out the long linen fibers, which they wove into the first true textiles. The cotton plant was found in India, and the fluffy fibers of its seed bolls—almost pure cellulose—were spun and woven into cloth. By hook or crook, men with no knowledge of chemistry had learned many ways of modifying materials through chemicals to make them more adaptable, more

durable, more beautiful. They had discovered how to turn clay into pottery and sand into glass; how to dye cloth and tan leather; how to ferment fruit juices, and how to smelt metals from their ores. Then suddenly, a century and a half ago, just after our own Revolutionary War, a handful of bold, brilliant experimenters laid bare the basic principles of chemical science.

With some knowledge of the elements and some comprehension of how they combine, definite chemical processing methods replaced rule-o'-thumb techniques. Sulfuric acid supplanted vinegar (acetic acid) and sour milk (lactic acid) as acidulating agents in bleaching and dyeing. Sodium carbonate, prepared from common salt and called "soda ash," replaced potash, the crude potassium carbonate leached out of wood ashes, in the manufacture of glass and soap.

So the chemical industry was born. Definite chemicals were put to work on the old job of making natural materials more to man's liking, and while some men were learning the first lessons in chemistry, others began to hitch power to tools, transforming them into machines. These machines created new jobs for chemicals.

When flax was spun and woven by hand, it was all very well to bleach linen by spreading it out on the grass in the sun for several weeks. But when one girl at the automatic spindles could spin 12,000 yards of yarn in the same time that an expert at the spinning wheel could produce a single yard—and with a corresponding increase in fabric turned out on the power looms—then the power-driven textile mills threatened to cover the land with unbleached greige goods. By a lucky historical coincidence, just at this time Claude Berthollet discovered the bleaching action of chlorine. This chemical whitened cloth in minutes instead of the days required by the action of sunlight. Furthermore, it worked as efficiently on a cloudy February afternoon as on a sunny July morning. Chlorine literally rescued the power textile industry.

Thus chemicals achieved a new function. Hitherto they had been employed to change or decorate materials: to transform fat into soap, to tan leather, to dye cloth. Henceforth they were called upon in the Machine Age to save time and to cut costs. In our own day chemicals have been put to an entirely new task, which is rapidly making changes in our way of life as fundamental as those wrought by the Industrial Revolution. Out of chemicals we are now producing our own materials tailor-made to suit our needs.

A century ago, stirred by their new knowledge, the early chemists eagerly began taking apart all sorts of things to learn of what elements they were made. It was a thrilling game, exciting as a lottery. The big prize was the discovery of an element that would blazon a man's name in the annals of science. Less sensational finds had great practical results. Two painstaking French pharmacists, Pelletier and Caventou, specialized in barks, leaves, and roots used in medicine, and they isolated the alkaloids quinine, cinchonine, and strychnine. In this way medicine, like industry, profited by being able to use active chemical principles. No longer was the malaria patient forced to down great nauseous draughts of "Jesuit's powder," the pulverized cinchona bark from which quinine is now extracted and made into neat little pills.

During this orgy of analysis a young German chemist, meticulous Friedrich Wöhler, uncovered an amazing chemical fact, very pertinent to our understanding of cellulose, the chemical that grows in every living plant. Until 1828, everyone firmly believed that a fundamental difference existed between inorganic compounds (mineral substances like gold and granite) and organic compounds, such as blood or beeswax, products of living animals and plants. That year Wöhler published the results of an experiment he had carried out four years earlier. Deliberately he had withheld this information, for he was a cautious, devout man and its logical conclusion was so startling that it appeared sacrilegious. By pouring ammonia water into a solution of potassium cyanate, Wöhler produced ammonium cyanate. In order to recover this colorless crystalline material in dry form, he evaporated the water, but on continued heating, instead of the long crystals of ammonium cyanate, he obtained smaller, needle-shaped crystals that on analysis proved to be urea. Urea, a constituent of urine, is a waste product of all animal life. In a test tube Wöhler had bridged the gulf between organic and inorganic materials.

This astounding discovery revealed new horizons. If Wöhler could produce urea without the aid of a kidney, surely other animal and plant products might be made in the laboratories. So reasoned Marcellin Berthelot, who succeeded in preparing first acetic acid (vinegar), then phenol (carbolic acid) and benzene, two products of coal tar, and finally alcohol. This opposite of analysis—putting together molecules instead of taking them apart—he christened "synthesis." His sensational triumphs inspired other chemists to engage in this seemingly miraculous feat of chemical creation.

Today a multitude of synthetic products play a

common role in the workaday world. They all replace or supplement some natural product. This great array of man-made materials—fibers, coatings, plastic and elastic compounds, abrasives and adhesives, colors, scents and flavors, leatherlike, rubberlike, and spongelike materials, even new alloys which, after all, are only synthetic metals—are all of them products tailor-made to do specific jobs more efficiently, more cheaply, than any of the raw materials provided by nature. This manufacture of materials has become a major function of chemicals. From serving us by modifying materials more to our liking and from saving time and money in manufacturing processes, chemicals have become the actual suppliers of synthetic raw materials.

Interwoven with the story of wood is the universal theme of man's use of his materials. First comes the natural product, firewood and war club; then the fashioned material, shingles and clapboards, bowls and bedsteads; later the processing of wood into paper, potashes, and wood alcohol; finally, the employment of pure cellulose in making fibers, plastics, and lacquers. From simple to complex, our use of cellulose has proceeded step by step from broad employment to highly specialized application.

That, as Kipling said, is another story.

But be it noted here that wood cellulose can now be prepared by either the sulfite or the sulfate process, so pure that it is available for chemical transformation into sheer, transparent films or the delicate filaments of rayon, into the lustrous coating of your television set or the rugged, resilient plastic of your car's steering wheel.

SMO ON THE AIR

Station	Sponsor	Time
	Monday	
WOI-FM, Ames, Iowa	Iowa State College of Agriculture and Mechanic Arts (Articles of Interest)	7:45 P.M.
	Tuesday	
WEVD, New York City	Wendell W. Rázim (Science for the People)	9:00 P.M.
	Wednesday	
CKPC, Brantford, Ont.	The Telephone City Broadcast Limited (Modern Science)	9:45 P.M.

The Editor of The Scientific Monthly will be glad to cooperate with university or other educational stations interested in securing scientific material suitable for broadcasting.

Tick Talk*

CORNELIUS B. PHILIP

Dr. Philip, principal medical entomologist and assistant director of the Rocky Mountain Laboratory of the U. S. Public Health Service, Hamilton, Montana, has had extensive experience with ticks and other insects capable of transmitting diseases to man (see THE SCIENTIFIC MONTHLY, 69, *281 [1949]). In 1947 he was a member of the Army Scrub Typhus Team in Malaya and in 1951 served as a consultant to the Air Force Arctic Aeromedical Laboratory, Fairbanks, Alaska. He was a colonel in the Sanitary Corps during World War II and is now in the Medical Sanitary Corps Reserve. He was honored with the USA Typhus Commission Medal for his work in the second world war.*

REFERENCES in the writings of the ancient Greeks attest the annoyed attention that ticks received even in those times, and undoubtedly they were even more annoying to our primordial forebears, who had none of the modern repellents to rely upon for protection. Some unique attempts must have been made (perhaps similar to those of today's Central African natives, who anoint their exposed bodies freely with fresh bovine urine collected in the cupped hands as from a faucet) to discourage attachment of arthropod pests. In 850 B. C., Homer wrote, "There lies Argos, the dog, full of vermin [*kynoraistes*]," and this Greek word has arisen to plague us in this era of binomial nomenclature. Homer is believed to have referred to *Ixodes ricinus*, the familiar castor bean tick of Europe.

That ticks attracted increasing attention from that time on is abundantly shown in many historical writings, but until the advent of systematic zoology in the eighteenth century ticks in the Old World were described and complained about under only two categories: the infamous "miana bug," or "teigne," which plagued caravan travelers in Persia, and an ixodid obviously allied to the above mentioned castor bean tick, which was noticed by Homer and his compatriots in Greece and other Mediterranean countries as especially annoying to dogs and other domestic animals. This early literature is full of superstitions and parables, for which there is space to mention only a few.

Pagenstecher in 1861 gave a scholarly review of all the early references that could be assigned to *I. ricinus*. Taking into account the present abundance of the brown dog tick, *Rhipicephalus sanguineus*, in the Mediterranean area, it is probable that at least this species also was concerned. It is not too surprising, in view of the grotesque early methods of treating various maladies, that crushed, engorged ticks fresh off animals should be seriously advised for treatment of open sores and other ailments. Such a concoction was even recommended as the chief base for an ancient love potion, and a notation from Pliny suggests its use as depilatory. Another quotation from Pliny reads, "The blood of the ricinus heals the sacred fire, which power it has in the animal kingdom in common with the earthworms, crickets, heads of the viper and goose grease." The "sacred fire" may be a free translation referring to a modern affliction. Aristotle gives repeated evidence of his familiarity with the source of tick infestation of animals incidental to wandering in the grass. The widely accepted early belief that ticks were disgusting creatures which consisted merely of sacs that became filled with the blood of their victims to the bursting point, and then died because they had no anus, seems to have originated with Pliny. Somewhat later this idea was enlarged upon because the alimentary tract of the tick appeared to terminate as a blind pouch to hold the blood of the host.

Several parables of early times make comparisons with the observed parasitism of the tick burying its head in the blood stream of its victims and remaining there for days without moving during its gluttonous repast. Petronius quotes the following parable: "I thus hope to die, as a dead one I do not feel ashamed; you, however, are so industrious that you won't look behind yourself! You see the little louse on others, but you don't see the 'tick' on yourself." The Scotsman Bobbie Burns was antedated here by several centuries.

Two kinds of vermin were thus recognized in

* Based on the annual invitational public address of the Entomological Society of America in joint session with the American Association of Economic Entomologists, Denver, Colorado, December 19, 1950.

this later literature. It is interesting to note that before the age of taxonomy morphological differences between the sexes, especially when they were fully fed, should result in calling the one "ricinus" and the other "reduvius." Methods of suggested control were naturally primitive, but one of the recommendations of Pliny was the application on infested and suffering animals of an ointment prepared by boiling lichens in sulfur. This has some wisdom akin to contemporary ideas of the utility of sulfur.

The miana bug (probably *Argas persicus*) must have been a real nuisance to travelers in Persia who stopped at caravansaries, for there were repeated reports of fatal attacks on strangers visiting the country. Obviously, local residents were not so affected, since the trouble was often referred to as "stranger's disease." It is probable that a virulent form of relapsing fever now known to occur in the Middle East may also have been involved. One of the drastic cures consisted of wrapping the patient in a freshly removed cow hide and anointing exposed parts with honey as the hide dried and contracted. Presumably this facilitated the squeezing out of the malady. The "stranger's disease" was even mentioned in diplomatic reports to European courts.

Some fascinating reports of encounters with the pigeon tick, *A. reflexus,* appear in early European literature. The custom of building dovecots adjoining upper bedrooms resulted in the invasion of the occupied premises. Physicians who treated persons attacked have given several lurid accounts. In one case the owner disposed of the birds and walled up the pigeon house. Two years later, he reported to his doctor with an erysipeloid swelling spreading from tick bites on the wrist to encompass the entire body. He had shortness of breath, palpitation, and dullness for an hour or so, followed by profuse sweating. The swelling subsided after about 15 hours. In another instance a family moved into a house that had been vacant for four years. The previous occupant had kept pigeons and chickens in the dwelling. The father of the new family developed generalized furunculosis, which was later contracted by his two children. When the family moved out, their trouble stopped. Within two days another family moved in, and the father and a child of the new occupants suffered from the same effects. On thorough disinfestation of the house the difficulties ceased. It seems likely that *Argas,* with contaminated mouth parts, was spreading the affliction.

Of interest here are the recent observations of Anigstein and his colleagues that extracts from adult ticks, especially after feeding, have an antibacterial factor that inhibits the growth of many types of bacteria in vitro. This probably has some significance with relation to the nonadaptability of certain pathogenic bacteria to residence in ticks.

Historical accounts in the writings of Livingston in 1857 during his missionary travels in tropical Africa contain what are probably the first references associating fevers with the bites of ticks endured while sleeping in native huts. The tick concerned, presumably *Ornithodoros moubata,* is one of our most domesticated arthropods.

In Madagascar, natives have reported a tick (*Ornithodoros* sp.?) which can cause death by its bite but to which the local residents have become immune. It is even reported that the ticks are useful to keep in the house to discourage raids by hostile tribes.

Only a relatively few kinds of mites are parasitic on the higher animals in one or more stages, but so far as known all stages of ticks—both the soft-bodied argasids and the "hard-shelled" ixodids—are entirely dependent for their development on the blood of vertebrate hosts. All vertebrates, excepting fishes but including amphibians, have been recorded as tick hosts. This parasitic habit, however, has taken on some remarkable deviations in various species in all parts of the earth, except in the extreme frigid zones. Likewise, the cycles of various kinds of disease agents which have become adapted to transmission by ticks present some fantastic adaptations to this varied tick-host relationship. This is particularly true of the piroplasms, such as cattle fever. This disease, incidentally, has the historical distinction of being the first to be demonstrated as tick-transmitted of a long line of subsequently discovered important arthropod-borne diseases. Because of the extreme variations both in the developmental cycle of the ticks and of the disease agents themselves, methods of control have been very complicated. In some cases only one stage of a given vector is involved; in others all stages may be adequate vectors, but infection is not transferred to subsequent generations. In still others there is adaptation of the infectious agents to transovarial passage as well. Obviously, the more hosts attacked at various stages, the greater the danger of the spread of animal and human maladies.

One of the most interesting recently discovered rickettsial pathogens that is adapted to a wide spectrum of tick hosts is *Coxiella burnetii,* the agent of Q fever. This has now been reported from all continents and in ever-widening localities; nine species of ticks have been found naturally infected.

A jack rabbit found dying near Ringling, Montana. Massive infestation of adult ticks in sparse hair along back caused fatal anemia by withdrawal of blood. (Philip *et al. J. Am. Vet. Med. Assoc.* [1935]).

Tick tissues and tick feces become massively infected, and the rickettsial agent is unusual in that it is filterable and can be extremely diluted in the laboratory. Titers in these materials as high as 10^{-10} have been reported several times. One titration of tick tissue by the writer was 1:500 billion (2×10^{-12}) for tick tissue. This dilution can be dramatically portrayed when it is stated that 1 gram of ground infected tick tissue could be diluted and still maintain an infectious dose for a guinea pig in each drop of liquid, to the equivalent of the amount of water going over Niagara Falls in 5⅓ minutes, assuming that an average of 200,000 cu. ft./sec. is spilled over that cataract. In other words, 8,745,000 gallons would have to spill over to exhaust the diluted gram of infectious tick tissue.

Tularemia is a bacterial disease often transmitted by ticks to man and may cause serious losses in his domestic stock. An epizootic occurred among heavily tick-infested sheep and jack rabbits near Ringling, Montana, in 1934. Forty per cent of 1320 yearlings were affected symptomatically, and 200 died. Infection was recovered from ticks and tissues from both sheep and hares; however, it is known that massive parasitism by ticks can cause death from secondary anemia which is due simply to withdrawal of blood. One moribund hare was found with a hemoglobin reading of only 20 per cent; 152 *D. andersoni* were found on this unfortunate animal, and no infection was demonstrated in either ticks or tissues. Jellison and Kohls have shown that domestic rabbits may be practically exsanguinated with as few as 60–75 adult female ticks feeding over a period of about twelve days.

The argasid ticks feed intermittently and for brief periods, like bedbugs, and produce smaller numbers of eggs than do the ixodids, which gen-

Pelts, and sick and dead sheep, and a dead jack rabbit collected during a tick-caused tularemia epizootic near Ringling, Montana.

erally remain attached to the host for some days. The often restricted host habits of the ixodids make the finding of acceptable animals more hazardous, and therefore their fecundity is considerably greater, even astonishingly so in certain species. Over 18,000 eggs were counted in one batch laid by a single *Amblyomma maculatum*. By comparison, most insects are much less prolific, and in addition are very much shorter-lived. There are some remarkable records of longevity of unfed argasids. One unverified report by Pantazi of eighteen years seems unlikely. But there are a number of records of five or six years or longer with occasional feedings, and Dr. Davis, of the Rocky Mountain Laboratory, kept an *O. turcata* for nine years without a blood meal from the time it molted and for an additional three and one-half years after one feeding.

The greatest fecundity of these species seems to be in proportion, fortunately, to the reduced chances of replacement. To ensure the survival of the species we could expect over the years that about one pair would be all that replaced each

parent female of the previous generation. Otherwise, with some thousands of eggs being laid by many ixodid females, we soon would be "swimming" in ticks before many generations had passed in a given locality.

A few species of parasitic mites are known habitually to penetrate the skins of their hosts. Ticks, on the other hand, customarily attach without burrowing in. There are rare records, however, of the complete penetration of the tick beneath the skin of its host. In this country, Portman and Dalke describe the pelt of a red fox which contained some 150 completely imbedded *A. americanum* in all three stages. Strangely, the connective tissue in which the ticks were embedded did not appear to have formed nodules or cysts around the ticks, as was reported by Bell and Chalgren in the skin of a cottontail infested with *I. dentatus*. Seventeen such nodules contained all three stages of the latter when examined. It is possible that the phenomenon reported by Trager of an immune reaction to tick infestation resulted in the engulfment of the attached tick by the edematous swelling of host tissue around the point of attachment. Species of *Amblyomma*, with their long rostellums, are observed especially to cause local irritation in the host, so that the feeding ticks appear to be partially embedded in the swelling skin. The long rostellum of *A. americanum* has even permitted authentic cases of attachment through socks.

In the vast population of arthropods in the world it is perhaps not surprising that some very common and ubiquitous insects pass almost unnoticed by most persons, whereas ticks of one kind or another are a familiar form of animal life to everyone in the temperate and tropical zones of the earth, because of their propensity for parasitizing man and/or his domestic animals. They affect the domestic economy of primitive and civilized peoples alike.

It is not strange, then, to hear all sorts of stories of the best way to get them off once they have become attached. The "drilling" apparatus of the tick consists of a fixed hypostome with immovable teeth (i.e., armed) and movable chelicerae with articulated cutting digits at the tips. As Nuttall has pointed out, the armature of the hypostome varies and seems developed with rows of recurved teeth in some proportion to the habits of parasitism of a given stage, especially in the genus *Ixodes*. Here there may be a bisexual difference where mating often occurs off the host, and only the female may require a blood meal for oviposition. In this case, she may have a well-armed rostellum, whereas that of the male is only feebly so. The larvae of *O. moubata* molt to the nymphal stage before feeding and hence are without teeth in the larval stage. Conversely, although the nymphs of the spinose ear tick have well-armed hypostomes during their several months' existence in the ears of the host, the adults resulting from last-stage nymphs that have left their hosts mate and procreate without another blood meal, and their hypostomes are unarmed.

The hypostomes of some species, particularly many *Amblyommas*, are especially long and heavily

Pelted sheep dead of tick-caused tularemia near Ringling, Montana. Sick and dead sheep are scattered among sagebrush in background.

The largest and smallest known ticks. Engorged females (left) of *Ixodes soricis*, the smallest, from a British Columbia shrew, of *Dermacentor andersoni*, Montana, about as large as a fingernail, and (center) of *Amblyomma varium*, the biggest, from a Venezuelan sloth; (right) male of the last-named.

armed with rows of rigid teeth. When the skin of a guinea pig with *D. andersoni* attached is peeled back, the mouth parts do not usually penetrate through it, but, under similar circumstances, those of attached *A. americanum* or *A. cajennense* will be seen protruding through it; yet the females of each fill up about equally rapidly.

The difference in firmness of attachment is shown when each is forcibly pulled loose. Both may take some skin and flesh, but the mouth parts of *andersoni* have practically never been left behind in our experience with literally millions hand-pulled with forceps from laboratory animals incidental to preparation of "tick-type" spotted fever vaccine; this happens more often with the *Amblyommas*, prevalent in the Southeastern United States and in Latin America.

Among the frequently reported methods of removal is the traditional favorite of unscrewing them, which, of course, is more likely to leave the mouth parts in the flesh than if simple firm traction is applied forward against the direction of attachment. Such reported popular means of removal as the use of vaseline to "drown" them out, use of turpentine or coal oil, running a pin through them, approaching them with a burning cigarette or match simply kill them *in situ*, as tests have shown. Tobacco or "snuss" juice and even Black Leaf 40 had no effect. Tinctures of iodine and merchurochrome seem not to have caused attached ticks noticeable discomfort, although one of each sex of *D. andersoni* changed positions in a capsule on an animal after an iodine application. A feeding female also moved to a new position in a large capsule 15 minutes after turpentine, leaving a strong aroma in the capsule, had been touched to another tick half an inch away.

On the other hand, there is evidence that some animals and people have a natural "aroma" that repels ticks. At least it is well known that certain persons under identical conditions of exposure do not become infested to the same extent as do others. Brennan reported a Missourian a few years ago who actually killed some unattached ticks confined on his skin in ventilated cells for 20 minutes or so.

Considering the fixed armature of the hypostome, and the ticks' resistance to forcible removal,

it is remarkable how easily and quickly they are capable of voluntary detachment. But no substance of our acquaintance will consistently cause them to let go of a living host before they have finished engorgement.

Only brief reference will be made here to tick control. A number of substances have been screened in recent years for acaricidal or repellent properties, by personnel of the Bureau of Entomology at Orlando, Florida, and Kerrville, Texas, of the Rocky Mountain Laboratory, and of the Naval Medical Research Institute. Smith and Gouck found that the repellents stocked by the Army—di-methyl phthalate and "6-2-2"—reduced tick attack if used every three days on clothing, and Cole and Smith considered another, Indalone (although malodorous), as one of the superior available and consistent substances, and confirmed *N*-butylacetanilide, which Brennan had reported to be especially effective, as "outstanding on basis of effectiveness alone." This also killed ticks *in situ* either when they were touched or when they were exposed to fumes, but it did not cause either *D. andersoni* or *A. americanum* to detach, even when they were confined in capsules.

It has been dismaying to learn that strains of flies and mosquitoes can become resistant to our recent potent insecticides. Also unwelcome news is the report of pest ticks in South Africa that are resistant to what were proving to be efficient acaricides. Whitnall and his colleagues have reported populations of *Boophilus decoloratus* which became resistant to standard arsenical dips and subsequently to benzene hexachloride, which was proving so beneficial to the stock industry. Toxaphene —used as a spray, but not as a dip—is now the toxicant recommended for tick control by the Kerrville Laboratory. The toxicity for domestic animals of this material requires careful management in its application, as recently reported by Radeleff and Bushland.

Although we know the rearing requirements of many Acarina, we are only slowly realizing the important parts different ecological factors play. Different species have different moisture requirements. Some chigger mites require constant high humidity, and in New Guinea repellent patch tests had to be conducted by Bushland in jungle tents rather than in the open laboratory less than a quarter of a mile away. Some *Ixodes* species require higher than ordinary humidity for storage and feeding, particularly *I. holocyclus,* the Australian paralysis tick. Some *Ornithodoros* live under extremely dry, desert conditions, and their tough, rugose bodies are well suited to resist desiccation.

Light has only barely been examined as a factor, although we have known that larvae or nymphs of some species like *D. andersoni* will often remain attached on animals in semidarkness, such as in a burrow or cage, until suddenly lighted by emergence of the rodent, exposure of the cage, or removal of the lid of a capsule, when numbers of engorged specimens let go almost simultaneously. This ensures better conditions for the resulting adults.

Some species of both mites and ticks are blind; others have simple eyes with which they undoubtedly react to light. Garnett and Sachtor reported that unilateral light sources of between 5 and 40 foot-candles affected their repellent tests by attracting *A. americanum.* Jenkins found he could train chiggers to respond either negatively or positively to light by conditioning. Smith and Cole showed that immature stages of *D. variabilis* were stimulated by gradually increasing the photoperiod of exposure corresponding to lengthening days in spring. We may need to pay more attention to these factors in experimental rearing and vector studies.

Dragging a muslin flag over tick-infested vegetation has become a standard technique for collecting appropriate stages. This method was used over a period of years in the Bitterroot Valley to study behavior of adult *D. andersoni* in two ways: (1) Their natural occurrence and persistence on a surveyed 40-acre tract, and (2) the tendency of liberated, marked ticks to migrate toward bait or away from a central station.

The studies showed quantitatively that peaks of abundance in the Bitterroot occurred in six successive years during the first two weeks in April regardless of "early, average, or late" spring, and also their almost complete disappearance by mid-June with arrival of hot weather. Ticks remained on the vegetation during rainstorms and could be collected at midnight, but were less alert during high winds. Ticks marked at the beginning of one season were very occasionally retaken toward the end of the second season. In confinement in nature, unfed *D. andersoni* adults have lasted into a third season. Elk, moose, and cattle ranged freely over the area and were undoubtedly responsible for considerable depletion on the survey tract. One tick with two seasons' colors on it was reported with some alarm by a passing rancher, but he was assured that we were not liberating "poison" ticks.

Second, unpublished observations revealed that marked ticks liberated at 5, 10, 25, and 50 feet under varying conditions and directions around a saddle blanket or other animal-scented bait

Tick "dragging" with a flannel flag in 9-Mile District of Montana—notorious as the first area in North America where Q fever was recovered from ticks.

tended to migrate toward the bait or toward a competitive, used game trail in another direction. Usually less than half the total were recoverable by flagging at a given checking operation, but most of these were either within a short distance of the liberation station or at 25 feet or less, moving in the direction of the bait. In two instances at 5 and 25 feet, where the stations were intentionally established on game trails, as many moved along the trails, up to 25 feet, as toward the bait. The slope or levelness of the terrain appeared unimportant, and travel with the prevailing wind did not seem to be slower than against it within 10 feet of the bait, probably because of nocturnal movement on the part of the ticks when the wind died down. Even in cases of counterattraction such as game trails, or at the 50-foot stations where the attractant was weakest, the marked ticks generally scattered in the direction of the bait, and it is probable that the presence of a bedded animal or an overnight camper would be much more attractive. Live animal bait, such as a caged rodent, was not tried. Very few of the 25-foot station ticks actually reached the bait, although they would be scattered in its direction up to 20 feet. Two to 5 ticks out of 50 from the 5-foot stations generally reached the bait in 24–48 hours, although a number would remain at the point of liberation up to two weeks or more, in spite of apparent repeated capture and reliberation in flagging.

Another method of checking migration was by the liberation of batches of 125 marked ticks at central points and flagging the surrounding areas daily. The percentage of ticks recovered at any one flagging was low, but was sufficient to indicate trends on a south slope compared to a level exposure with similar vegetational cover, through a week of prevailing westerly winds. During the first three days of cool weather none was caught beyond 10 feet of the point of liberation. The first warm day, however, accelerated the general movement upwind from both stations to 15–20 feet; 50 and 26 ticks were beyond 5 feet on the upwind side and only 4–9 had moved on the downwind side at this time. This general disproportion in the two directions continued during the next three weeks, although the actual stimulant was not determined, since there were no nearby game trails to interfere, and the direction of the wind per se may or may not have been responsible. On the twenty-

fourth day 3 had moved upwind 35–40 feet, and only 3 in all were taken between 5 and 12 feet from the downwind side of the hill station; at the level station 5 were taken 15–25 feet upwind, and the same number only between 3–9 feet. Thirty-one and 32 were recaptured at this late flagging.

The tendency to concentrate along game trails and roads is well known, although the repeated accusation that ticks drop out of overhanging branches or jump off the vegetation onto passing horseback riders is not credible. It appears that they respond to adjacent hosts by scent, vibration in passing, passing shadows, or combinations of these. William Mann, traveling in Persia in 1915, noticed that ticks with long legs infested sandy, arid, scrub areas, where stock were accustomed to lie in shelter. He called them "cursorial ticks" because they pursued him within a distance of 10 feet even though he changed his direction. The species was identified for him as *Hyalomma savignyi*, an ixodid. The female has a spiderlike appearance, and the species is a known transmitter of disease to animals in the Far East and Africa.

I should like to terminate this "Tick Talk," with a quotation from Holland's *Moth Book*, which I'm sure has stirred many of us in our younger "bug-hunting" days, as it did me:

> When the moon shall have faded out from the sky, and the sun shall shine at noonday a dull cherry-red, and the seas shall be frozen over, and the ice-cap shall have crept downward to the equator from either pole, and no keels shall cut the waters, nor wheels turn in mills, when all cities shall have long been dead and crumbled into dust, and all life shall be on the very last verge of extinction on this globe; then, on a bit of lichen, growing on the bald rocks beside the eternal snows of Panama, shall be seated a tiny insect, preening its antennae in the glow of the worn-out sun, representing the sole survival of animal life on this our earth—a melancholy "bug."

He could logically have substituted "mite" for "bug", because a generalized, nonparasitic, lichen-eating oribatid mite could as easily have been that last surviving arthropod.

Brues has found some water mites in thermal springs as hot as 50.8° C and with a pH of over 9.6. Had Holland lived into this decade to write his fanciful epitaph, considering the newer conception of the ultimate engulfment of the earth by an expanding sun, as depicted popularly in *Time* (Nov. 20, 1950), he might have concluded a mite differently, such as

> . . . in the futilely protective shadow of a protruding bit of agatized rib of a long-since extinct whale, itself the last remnant of a once domineering type of animals called vertebrates that barely survived the catastrophic developments of the so-called atomic age when the world was young and lovely for living things, . . . in this shimmering shadow in a now bleak and almost lifeless world steaming in the writhing heat of a merciless, expanding ball of fire in the heavens, and beside the ever-boiling, cauldron springs of the North Pole, crouches an anxious, solitary water mite, the sole survivor of animal life upon this agonized, liquidating planet. There will be no chronicles of her life cycle, and the validity of her scientific name shall be a matter of great unimportance.

The Role of Cybernetics in Physiology*

STANTON H. COHN and SYLVA M. COHN

Dr. Cohn has been with the U. S. Naval Radiological Defense Laboratory, San Francisco Naval Shipyard, since 1950, and is at present head of the Clinical Radiobiology Branch of the Biological and Medical Sciences Division. He previously worked for two years on the chemistry of explosives, then spent three years with the U. S. Army in Europe in the chemistry laboratory of a general hospital, and four years as a research radiochemist. Mrs. Cohn had done research on cathode-ray tubes and servomechanisms. She was head mathematician for the Special Operations Division, Operations Analysis Section, of the San Francisco Naval Laboratory when she retired in 1951 to take up the more exacting duties of domestic life.

Those engaged in arts and science, most Gracious Emperor Charles, find many obstacles to the exact study and successful application of them. In the first place, no slight inconvenience from too great separation between branches of study which serves for the perfection of one Art. But much worse is the mischievous distribution among different practitioners of the practical application of the art. This has been carried so far that those who have set before themselves the attainment of an art embrace one part of it to the neglect of the rest, although they are intimately bound up with it and can by no means be separated from it.

—VESALIUS (1542)

We have inherited from our forefathers the keen longing for unified, all-embracing knowledge. The very name given to the highest institutions of learning reminds us, that from antiquity and throughout many centuries the *universal* aspect has been the only one to be given full credit. But the spread, both in width and depth, of the multifarious branches of knowledge during the last hundred odd years has confronted us with a queer dilemma. We feel clearly that we are only now beginning to acquire reliable material for welding together the sum total of all that is known into a whole; but, on the other hand, it has become next to impossible for a single mind fully to command more than a small specialized portion of it.

I can see no other escape from this dilemma (lest our true aim be lost forever) than that some of us should venture to embark on a synthesis of facts and theories, albeit with second-hand and incomplete knowledge of some of them—and at the risk of making fools of ourselves.

—SCHRÖDINGER (1945)

IN THIS age of specialization where one man is the master not of a whole field of thought but, rather, of a very small portion of that field, the need for correlation of the various special sciences into an integrated, coherent picture is becoming daily more urgent.

In 1542, Vesalius[1] wrote the words quoted above, deploring the state of affairs in which the scientific worker was separated from a complete knowledge of the field of his endeavor. In the four hundred years that have elapsed since the time of Vesalius, the situation has grown much more acute for the individual, and today the plea for correlation of the various branches of science is reiterated by such leading scientists as Schrödinger, whose statement is also quoted here.[2]

We may not again see another Leonardo da Vinci, "perhaps the most versatile genius of whom we have any record,"[3] who was proficient as a painter, mathematician, philosopher, scientist, musician, and engineer. Since his time few men have taken the whole of knowledge for their province. One of these was Gottfried Leibnitz, who has been characterized as "the Aristotle of the Seventeenth Century"[3] and who was perhaps "the last human being to undertake the mastery of all existing knowledge."[3] Leibnitz was noted as a "brilliant mathematician, physicist, geologist, philologist, historian, and editor" and "an important personage in public affairs."[3] In the nineteenth century another scholar, Hermann von Helmholtz, made notable contributions to a number of fields—medicine, neurophysiology, physics, mechanics, aerodynamics, and mathematics.

The appearance of so few general scholars among the many learned men of the past few

* The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or as reflecting the view of the Navy Department or the Naval service at large.

centuries is closely related to the growing tendency for knowledge and learning to be treated along increasingly specialized channels, with the universal aspects receiving correspondingly less attention. With the growth of scientific knowledge, it may be only by the unification of the language and basic concepts of various fields of learning that man can once more attempt to embrace a large area in the field of knowledge. As Dingle points out in his provocative and stimulating book *Through Science to Philosophy*,[4] elementary experiences have been rationalized into schemes known as physiology, psychology, biology, mechanics, thermodynamics, etc., each covering only a portion of the whole field of phenomena, and each expressed in a particular set of terms and a particular set of laws. All the fields of scientific endeavor have similarities, and advances in the techniques and organization of one field may very well be applicable to another. When, however, one tries to go outside his field into a neighboring one, the difficulties of learning the new language and the new laws are almost insurmountable obstacles to comprehension. Much of the work to be done, therefore, in the way of scientific endeavor is that of correlating these separate fields into one homogeneous rationalization. As Dingle points out, it is in the borderline area between the various fields that the greatest advances are to be made. Our century is witnessing a wide-scale invasion of this territory, but the tradition goes back at least to the seventeenth century.

Application of the Physical Sciences to Physiology

Some of the earliest attempts to apply the concepts of physics to biology were made by Santorio and Borelli, two exponents of the iatrophysics school of the seventeenth century. The tradition was carried forward by Descartes who, conceiving the body as a machine with the heart acting as a pumping plant, worked out his hypotheses along physicophysiological lines. Similar progress can be traced in the iatrochemical school of the seventeenth century, beginning with Von Helmont and Du Bois. In the eighteenth century, Lavoisier made further advances in delineating the chemical cycle of life. At this time, also, Galvani discovered animal electricity, or "galvanism," and Volta did further work on the application of the electricity of physics to living organisms. This correlation of the physical and physiological sciences has been continued and enlarged upon up to the present day.

Some of the pioneers in this work of correlation at the present time are Norbert Wiener and the group of men associated with him. It is just this challenge of the correlation of two specialized fields of knowledge that Professor Wiener wishes to meet. He says of his purpose:

> For many years Dr. Rosenblueth and I had shared the conviction that the most fruitful areas for the growth of the sciences were those which had been neglected as a no-man's land between the various established fields. . . . It is these boundary regions of science which offer the richest opportunities to the qualified investigator.[5]

Wiener and his associates are tying together several fields of knowledge: the physical sciences, mathematics, statistics, and electrical engineering, and the biological science neurophysiology. The focal point of their activities—the common denominator for these various fields—is the interest in machines which compute and control, and the systems in the human mechanism which perform similar functions.

The name given to this new, unified field of endeavor is "cybernetics," taken from the Greek word for "steersman."[5] The word "governor," a Latin corruption of the same basic Greek word, is closely related in meaning and can be said, in the new terminology, to describe a "cybernetic device."

The story of the development of cybernetics extends back only ten years. The first important date in cybernetic history is 1942, the year in which Rosenblueth, Wiener, and Bigelow presented a new approach to the study of voluntary human activity in a paper presented to a meeting held under the auspices of the Josiah Macy, Jr. Foundation.[6] This paper was published in 1943. In the winter of 1943 Wiener and von Neumann, of the Institute for Advanced Study, convened a meeting of various persons who had become interested in the new ideas being promulgated, in which engineers, physiologists, and mathematicians participated.[5]

By 1946 there was greatly accelerated progress of the new work. In the spring, the neuropsychiatrist Warren McCulloch arranged several meetings, again sponsored by the Macy Foundation, in which psychologists, sociologists, anthropologists, neuroanatomists, and neurophysiologists took part. Cybernetic ideas were thus widely disseminated, and it was decided to meet semiannually for an exchange of ideas among the various groups represented. The results of these further meetings have been presented in a series of papers on cybernetics.[7–9]

In 1946, also, an experiment of prime importance—one of the first trials of the new theory—was performed by Wiener and Dr. Rosenblueth at the Instituto Nacional de Cardiología, in Mexico City.[5] In 1947 a second work of great cybernetic

importance, that of "designing an apparatus to enable the blind to read the printed page by ear" was performed by Dr. McCulloch and Mr. Pitts. On the basis of this work, these two men developed a new theory of the physiology of the visual cortex, drawing on anatomical, mathematical, and engineering principles, which was presented at a 1947 meeting.[5] It was at this time that the term "cybernetics" was devised to cover the new field of activity. In the fall of that year Wiener began work on his book, which was published in 1948.

The development of cybernetics, however, has its roots in the last century of work in mathematics, physics, engineering, and physiology, and in order to understand the work of Wiener and his associates, it is necessary to understand the background from which he drew his inspiration.

Physiology in the Age of Power

The nineteenth century was the "Age of Power." It saw the development of the machine, and concomitant with it there arose a mechanistic philosophy of life and a mechanistic interpretation of the life processes. If there is one law that marks this era definitively, it is the principle of the conservation of energy. This principle, which is expressed in the first law of thermodynamics, has been characterized as the greatest generalization in natural science. But it is not the final word.

It is true that many phenomena can be described by application of the energy principle alone, as is borne out by the remarkable success of Rashevsky in applying this principle to processes of biology and physiology.[10] Rashevsky expresses his profound belief in the energy principle as the basis on which to build biology: "All human activities may be considered as biological manifestations and the principle of maximum energy flow may be applied to all of them. . . ."[10]

Nevertheless, it is now recognized that the energy principle, if applied exclusively, leaves no room for the explanation of the role of information and intelligence in any rationalization of the ordered life processes. Indeed, it does not provide an adequate basis for the description of life, either, as is well brought out by the fact that physicists and biologists are split on the question of whether some new principle is needed to explain life.

Brillouin, in a searching article entitled "Life, Thermodynamics, and Cybernetics,"[11] classifies those who hold opinions on this subject into three groups: those who believe that life can be explained in terms of the present concepts of physics and chemistry; those who feel that "something more is needed before we can understand life;" and those who believe that life cannot be understood without reference to a "life principle," and that the behavior of living organisms is completely different from that of inert matter. That there can be such a diversity of opinions would lead one to believe that the application of the energy principle which has dominated scientific thought up to the present decade has not met the requirements for a basic principle that will unify the physical and biological sciences.

Science has advanced beyond the mechanistic stage, however. Just as the nineteenth century was the Age of Power, the twentieth century is the Age of Communication and Control. It is not enough to make a powerful machine, having the ability to do many times the work of man. There must be an intelligent application of this energy—it must be controlled. Just so, the human body has intelligence which utilizes information in directing its activities. The study of these in both mechanics and physiology is enlarging our field of knowledge at the present time. As it happened, much greater progress was made in the fields of electronics and mechanics in the systemized study and presentation of control and communication. But since there are parallel functions in the field of physiology, it remains to apply the principles formulated to the latter field. This, then, is the work that Norbert Wiener has undertaken. He summarizes this by saying:

> In the nineteenth century . . . all the fundamental notions are those associated with energy, and the chief of these is that of potential. The engineering of the body is a branch of power engineering. Even today, this is the predominating point of view of the more classically minded, conservative physiologists. . . .
>
> Today, we are coming to realize that the body is very far from a conservative system. . . . In short, the newer study . . . is a branch of communication engineering. . . .[5]

The discussion of cybernetic principles can be grouped around two very important concepts: the servomechanism, and negative entropy.

As mentioned above, the wonderful machines that have been developed in the past hundred years or so need intelligence for their operation. What is the nature of the machine brain that permits our factories to operate like automata? The key to this story lies in an elucidation of the servomechanism. Literally translated, servomechanism means "slave mechanism." It is a system whereby a signal, or bit of information, with a tiny amount of power, controls and directs large amounts of power capable of doing much useful work—thus the machine becomes the slave of the intelligence.

The servomechanism is not a particular, single

machine. Rather, it is a closed loop system, a *scheme* for setting up various types of equipment. Many of the systems of the body appear to function in such a manner that the elements involved can be said to be arranged as the elements of a mechanical servomechanism, and the mathematical techniques that have been worked out for the mechanical "servo" are now being reworked to apply to biological and physiological phenomena.[12]

The science of automatic control and the theory of the servomechanism—a development of the past fifteen years—have led Wiener into new techniques and theories on the understanding of human activities. The central concept of which Wiener has made use is that of negative feedback, as Eisenhart points out in an excellent review of cybernetics.[13] The feeding back of a signal from the controlled member is the heart of the whole servomechanism loop and makes its behavior different from the responses of other systems.

The performance of a servomechanism may be characterized as follows. Information in the form of messages or stimuli is fed to a system by pickup devices or receptors. These messages are sent through communications means—circuits or nerves—to a central computing system, or brain and reflex center. This center then compares the incoming signal with a desired value, and operates on the difference, or error, to produce a signal that is then fed to the power equipment, or effector organs. The latter then move in such a way as to alter the conditions producing the incoming information, and bring it closer to the desired value. Especially to be noted are the closed loop nature, or circularity of the system, and the fact that the system embraces the object upon which it operates. As a matter of fact, in mathematical analyses of mechanical systems, it is not possible to distinguish between the controlling and controlled portions of the systems.

This analysis has been well established for mechanical automatic control systems, but it is new and highly revealing when applied to the human organism.

Wiener provides an excellent illustrative example. Consider the action of picking up a pencil. This action is initiated by the desire to pick up the pencil. Note, as Wiener points out, that we do not will ourselves to move in a particular sequence a certain group of muscles. The receptors feeding information into the control loop are the eyes, which give information on the position of the object. This information is sent to the computing center, the brain, via the nerves. The brain then computes the amount by which we have not yet picked up the pencil—that is, the error of the system. We then have the difference in positions of our hand and the pencil. At the same time, this scheme also requires that information be sent into the central computing system regarding the position of the arm and the hand with relation to the body. Part of this information is visual, but not all. Some is conveyed by means of the proprioceptive sense.†

The brain acts upon the information received, and produces a proportional or more complicated type of response. This signal is then sent through the nerves of the efferent nervous system to the muscles, which then perform the activity that will bring about the accomplishment of the desired event.

We would expect that if the servo theory were indeed to hold true, it should be possible to verify by experiment the mathematical prediction of the performance of the system. A highly interesting experiment of this type was carried out in 1946. It is known that certain adjustments of servo systems will cause these systems to go into oscillation. The frequency of the oscillation is a function of the values of the system parameters. Wiener and Rosenblueth performed the following experiment. They studied one of the muscles of a cat—the quadriceps extensor femoris—by cutting the attachment of the muscle, fixing it to a lever under known tension, and recording its contractions when the muscle was loaded to the point where a tap gave rise to automatic jerking movements, usually spoken of as clonus. They thereupon compared the frequency of oscillation in relation to the frequency as predicted from the "constants" of the system. Although the system is not linear, and thus analysis becomes rather complicated, it was possible to make a mathematical estimate of the period of vibration, which was found to be 13.9 cycles per second. Observed oscillations varied between 7 and 30 cycles, but generally remained within the range of 12–17 cycles per second, which shows remarkably good agreement for such a problem.

Although the feedback mechanism is the central theme of cybernetics, another factor is of great importance also, and that is communication. There can be no control unless some message is fed into the system as a command signal, and there will be no feedback unless a signal is sent over communica-

† Proprioceptive sense: The tendons, joints, and skeletal muscles contain receptors which respond to the stimuli of pressure and stretch. These receptors supply information via afferent fibers to the central nervous system regarding the position and movement of the part of the body in which they are located.

tion circuits. Thus Wiener, in developing cybernetic theory, is forced to include the science of communication. In making his analysis, Wiener found that the amount of information in a system, which is a measure of its degree of organization, can be measured by a quantity which turns out to be the negative of the physical quantity called entropy. What is entropy, and what is its physiological importance?

It has been found in thermodynamic experiments that there are processes that are irreversible, not in that any energy is destroyed in them (as, indeed, this is not possible), but only in that the quality of the energy (as measured by its ability to do useful work) is lowered. This process is called "thermodynamic degradation," and it is measured by the quantity entropy, which is formulated in precise mathematical terms. Moreover, it has been found that irreversible processes result in an increase in entropy, whereas reversible processes are marked by constant entropy. Inasmuch as all processes fall into one or the other of these two classes, the second law of thermodynamics has been formulated: "The entropy of the universe is increasing."

A body in thermodynamic equilibrium—an undifferentiated body, or one in a high state of disorder—has a high entropy. A body in a complex (i.e., a well-organized, or differentiated) state, has a low amount of disorder, or a low entropy. The amount of "order" possessed by a body can be expressed by the reciprocal of the quantity that expresses the disorder, or entropy, according to Schrödinger.[2] This quantity, the reciprocal of entropy, is called "negative entropy," or "negentropy."[14]

Wiener suggests that perhaps man may be considered a "metastable Maxwell demon," which decreases entropy. Schrödinger has offered the hypothesis that man feeds on negative entropy, "to compensate the entropy increase he produces by living and thus to maintain himself on a stationary and fairly low entropy level."[2] Brillouin sees brilliantly the connection between Wiener's concept of information or degree of organization as negative entropy, and Schrödinger's concept of the complex organism as a body feeding on negative entropy—i.e., organization and order—and from these suggests that a generalized description of all the ordered processes, among which is life, can be made.

Heretofore, the first and second laws of thermodynamics have been applied only to isolated, or "closed," systems. No way has yet been devised to measure entropy in "open" systems, the class of systems that includes all living organisms. Thus, although progress has been made in defining entropy in open systems qualitatively, it remains to find a way to make a quantitative measurement of entropy in these systems. This problem is of the greatest importance, because, as Brillouin points out, "it does not make sense to speak of a quantity for which there is no operational scheme that could be used for its measurement."[11]

Several investigators have already attacked the problem of making the generalized concept of entropy applicable to the new situations in which it is being considered. Brillouin discusses some of the problems arising from the application of the concept of negentropy to various types of information.[14] Ostow has done further work on this problem, in taking up the application of the entropy concept to psychic function.[15] Raymond has put forth the suggestion that the entropy of a system be defined as "the sum of the positive thermodynamic entropy which the constituents of the system would have at thermodynamic equilibrium and a negative term proportional to the information necessary to build the actual system from its equilibrium state," with the definition applied to open systems by closing them momentarily.[16]

We seem to stand on the brink of understanding; perhaps here is the clue that will determine whether life is to be explained in terms of known physical principles, or whether a new element must be added—the enigma that puzzles so many of our leading scientists today.

References

1. Vesalius, A. Trans. from *De Humani Corporis Fabrica.*
2. Schrödinger, E. *What Is Life?* New York: Macmillan (1945).
3. Barnes, H. E. *An Intellectual and Cultural History of the Western World.* New York: Random House (1937).
4. Dingle, H. *Through Science to Philosophy.* Oxford: Clarendon Press (1937).
5. Wiener, N. *Cybernetics, or Control and Communication in the Animal and the Machine.* New York: Wiley (1948).
6. Rosenblueth, A., Wiener, N., and Bigelow, H. *Philosophy of Science,* **10,** 18 (1943).
7. Foerster, H. von, Ed. *Cybernetics: Circular, Causal and Feedback Mechanisms in Biological and Social Systems.* Transactions of the 6th Conference, March 24–25, 1949. New York: Josiah Macy, Jr. Foundation.
8. *Ibid.* Transactions of the 7th Conference, March 23–24, 1950. New York: Josiah Macy, Jr. Foundation.
9. *Ibid.* Transactions of the 8th Conference, March 15–16, 1951. New York: Josiah Macy, Jr. Foundation.
10. Rashevsky, N. *Mathematical Biophysics.* Chicago: Univ. of Chicago Press (1948).
11. Brillouin, L. *Am. Scientist,* **37,** 544 (1949).
12. Kreezer, G. L. *Science,* **110,** 681 (1949).
13. Eisenhart, C. *Ibid.,* **109,** 397 (1949).
14. Brillouin, L. *Am. Scientist,* **38,** 594 (1950).
15. Ostow, M. *Ibid.,* **39,** 140 (1951).
16. Raymond, R. C. *Ibid.,* **38,** 273 (1950).

The Engineer and the Fundamental Sciences

C. G. SUITS

The author is a physicist, whose specialties include nonlinear circuits, vacuum tube methods of harmonic analysis, and the study of high-pressure arc temperatures by sound waves. He has been with General Electric Company ever since he took his D.Sc. at the Technische Hochschule, Zurich, in 1929. From 1940 until 1945 he was assistant to the director of research; then he succeeded William D. Coolidge in that position. His article is based on an address given at Yale University during the celebration of the centenary of the School of Engineering last October.

IN DEVELOPING my thesis, I will have much to say about technology, by which I mean that complex of science, engineering, and experience that is the foundation of industrial know-how, and which depends heavily upon engineers and scientists for its present strength and future development. Here I wish to examine the relationships between science and engineering and, particularly, to point out how highly developed and interdependent these relationships have become in the research and advanced engineering phases of a highly technical industry. To gain perspective, let us look briefly at engineering and science in the early days of American industry.

Primitive Industry and Early Science

It is clear that, at the start of the industrial revolution, around 1770, and during the industrial development that extended into the 1850s, empiricism rather than science was the rule. During this period, neither science nor engineering was recognized as a component of primitive industry. The foundations of modern industrial technology were, however, being laid in the scientific work of this same period. In the electrical industry, modern technology is built upon the early work of Coulomb (1736–1806), Ampere (1775–1836), and Faraday (1791–1867), followed by Maxwell (1831–79), Hertz (1857–94), Henry (1797–1878), and many others. Their researches, largely accomplished in a university environment, provided the observational facts and interpretation that became the basis for electrical engineering practice. The mechanical industries were similarly generated in fundamental researches of Newton (1642–1727), Carnot (1796–1832), and Joule (1818–89), among others. In chemistry, I suppose the names of Lavoisier (1743–94), Priestley (1733–1804), Scheele (1742–86), and Dalton (1766–1844) must be reckoned among the pioneers whose work was later to support the engineering foundations of the chemical industries. The few names I have mentioned by no means complete the list of pioneers of science upon whose work, translated into engineering terms and techniques, industry built a large structure.

The development of machines, especially Watt's steam engine, initiated the factory system and the Industrial Revolution, but the primitive industry that was thereby born drew but little of its strength from science and engineering. Watt's steam engine, Cartwright's power loom, Hargreave's spinning jenny, the cotton gin of Eli Whitney, and many similar machines, employed in their development a very small portion of science and a large content of mechanical inventiveness. The later phenomenal growth of modern industry could not have taken place, however, without the foundations in early natural science which developed independently of, and concurrently with, primitive industry.

The Engineer in American Industry

The real beginnings of engineering are of considerable antiquity, but the trained engineer appeared on the American industrial scene around 1850, at about the time many of our engineering schools, including the Yale School of Engineering, were founded in this country. The period between 1850 and 1900 was, among other things, the age of inventors. In addition to the trained engineer, who was making his way into industry, the early inventor played an important role in the transla-

tion of scientific facts into embodiments of practical utility. Industrial technology during this period was not yet so involved, nor basic scientific knowledge so complex, as to require intense specialization. Hence, a single talented individual could comprehend a broad area of industrial skill and related technical knowledge and could excel in conspicuous individual inventiveness. In the industry with which I am associated, it was the inventive genius of Bell, Stanley, Elihu Thomson, Edison, and others who translated the science of Faraday, Henry, Maxwell, and Hertz into products capable of manufacture and sale.

The increasing complexity of both science and its application led to the gradual development of engineering and of the engineer as the specialist who reduces the laws of natural science to the more or less exact practice of analysis, design, and construction. Of course, engineering does not concern itself solely with the application of science. Although this is a large and increasing content of engineering practice, the application of experience—and especially the extrapolation of experience—are important functions of engineering. The traditional inventor, as an individual with great natural aptitudes and a smattering of science, has almost disappeared as a logical consequence of the increasing technological complexity. Natural aptitudes of inventiveness have not, of course, disappeared. They have simply ceased to be individually conspicuous because, in modern technology, individual effort merges into a background comprising a great manifold of highly specialized technical skills.

The Birth of Modern Science

Consider the year 1890 and some of the significant events associated with it. It is well known that the scientists of the time felt that most of the fundamental laws of matter—represented by the knowledge of electricity, magnetism, mechanics, and thermodynamics—had been observed and interpreted, and that refinement of detail rather than new discovery would comprise the future of science. The electrical industry had its beginnings at about this time, originating in inventions based on the work of early electrical scientists. With minor exceptions, however, no scientists were employed by industry—a remarkable fact, in view of the many applications of science that were being made at that time. This situation can be understood, however, in terms of the traditions of primitive industry and the philosophy of early science. Early scientists felt that the adapting of the laws of nature to the practical uses of man involved a stigma, and that science was pure only if it was sterile. The men of early industry, on the other hand, knew that their experts had been trained almost entirely by working experience; hence, the concept of academic training for industry was contrary to all practice. It cannot be said that these early ideas have been thoroughly dissipated even now. I hope that my readers do not share these feelings concerning the debasement of science, for I shall have occasion to describe brazen instances of the application of new scientific discoveries to practical use; and I may as well confess that such cases give me much inner satisfaction. Furthermore, such wickedness seems to be on the increase!

The well-defined boundaries which science seemed to have in 1890 soon disappeared. Roentgen discovered his famous X-rays in 1895, and Becquerel discovered the radiation emitted by uranium in 1896. The electron was discovered by many investigators, but was first identified and interpreted by J. J. Thomson in 1897. In 1900 the Curies discovered radium, and Max Planck formulated the beginnings of the quantum theory. In 1903 Rutherford and Soddy correctly described and interpreted natural radioactivity. This span of eight years was in that year and against this background that the world had seen, and the era of modern science had its unmistakable origins in this flood of important new discoveries. The most significant result of this exciting period was the disappearance of the previously well-defined boundaries of science; it is a remarkable fact that, more than fifty years later, in spite of tremendous research effort in laboratories throughout the world, the boundaries to new scientific discovery cannot even now be seen. Before 1900 industry had not yet embraced science, but it was about to do so, for it was in that year and against this background that the first scientific research laboratory was established in industry. Scientists thus began to play a direct role in industrial organizations and to develop their functional relationships to engineering.

By 1900 the engineer in industry and his industrial functions were well established. To be sure, engineering was by no means as specialized then. In General Electric, for example, only four specialized skills in engineering could be distinguished: civil, mechanical, mining, and electrical engineering. The engineer in industry was likely to be engaged in a variety of technical activities involving the design, construction, testing, and operation of industrial equipment and processes. He applied what science was available to him, but large factors of experience, judgment, and courage entered into his designs. This is, of course, no less true today.

Around 1900 the engineer and the scientist could be clearly distinguished as separate professional specialists. In the first place, the engineers were to be found largely in industry, and the scientists were almost entirely in the universities. Scientists in industry were somewhat apologetic concerning their defection from professional tradition; and industrial engineers, on the other hand, were equally apologetic over any dealings with scientists, who were known to be a thoroughly impractical and visionary lot.

This distinction between the scientist and the engineer was, moreover, aided by dress and demeanor. The scientist of the times was likely to look like a scientist in the classical sense, whereas the engineer frequently looked the part and affected a manner befitting a thoroughly practical man. When I first came to industry, one could still find in our Schenectady plant a number of picturesque individuals who were reverently pointed out as "real" engineers. They were pioneers who had grown up with the electrical industry and who embodied the early traditions of the profession to a conspicuous degree. They wore their hats at work, indoors and out, occasionally spat upon the floor, and were somewhat given to profanity. They were distrustful of theories, especially those expounded by young men just out of college. New developments in science reached them by an exceptionally circuitous route, if at all, and they were almost entirely spared from direct contact with scientists in the normal course of their engineering activities. That professional complexity was to come later! They may have remembered, in contemplative moments, the period some forty or more years before when they were young engineers entering industry. *They* were *then* the impractical technicians with their theories and their mathematics, who subsequently had to establish their worth with the practical men in the infant, but rapidly growing, electrical industry.

In the early days, the technologists were the practical men, aided and abetted by inventors, and guided in analysis and design by engineers who first translated the electrical phenomena of Henry, Faraday, and Maxwell into particular embodiments of sufficient utility to permit the beginnings of a manufacturing enterprise. Engineers soon became the keepers of industrial technology, and they have for many years carried forward its development. Scientists appeared on the industrial scene fifty years after the engineers, and their work has contributed to expansion and diversification, particularly in the electrical, chemical, and communications industries, and has led to the great present-day growth of industrial laboratories.

Although the process has been going on for some fifty years, the extent to which science has now been integrated into the industrial complex has not been generally appreciated. For example, the early and successful employment of scientists and engineers in the electrical, chemical, and communications industries has not by any means established a pattern throughout industry. There are manufacturing businesses in our country, with an annual sales volume of hundreds of millions of dollars, which employ no scientists and few engineers. The extent to which science and engineering have been applied to industrial technology thus varies widely with industries. In some industries the techniques of employing engineers and scientists have hardly been explored, and in others scientists and engineers work together on complex technologies as vital to the business as its manufacturing and sales functions.

Technological Complexity and Professional Specialization

The development and increasing complexity of industrial technology have been paced by the increasing technical specialization of its practitioners. In engineering alone there is now a great variety of technical specialization. Although the engineering curriculum at many schools is extensive, I suspect that there are still some engineering specialties not included in training programs. The electrical industry originally employed only four professional categories of engineering, whereas the number is now very much greater. In the G-E General Engineering Laboratory, one can distinguish sixty-two separate fields of engineering, and the company-wide total undoubtedly would be much greater. A further index of specialization is provided by the number of national technical societies that are now in existence. In the field of engineering, for example, there are at least 135 national engineering societies in this country.

The same specialization has taken place among scientists and their national professional societies. The terms "physicist," "chemist," and "metallurgist" are now useful only as broad generalizations; they no longer denote definite fields of scientific specialization. It is not possible, at present, to be a specialist in physics. One might hope to encompass the specialized knowledge associated with a narrow field of physics, if this field is not expanding too rapidly; for example, classical acoustics, sound, heat transfer, and thermodynamics may present this possibility. But in the rapidly growing fields of modern physics this is impossible. Some

years ago when the atomic nucleus was a novelty, one might have specialized in nuclear physics, but today the field is too broad and there are many specialists within this area, including reactor, radiation, and cosmic ray physicists. A similar, but less extensive, degree of specialization is probably developing currently in solid-state physics, where spectacular progress is being made in the art and science of the semiconducting elements.

It is a fact that modern developments in science and engineering are becoming more and more complex. As a first approximation to the truth, one is tempted to conclude that all the simple discoveries have already been made, but this, of course, could hardly be true. Each new tool of science opens up a new vista that could not be seen with the older, and generally simpler, tools. The electron microscope has unlocked a world that light microscopy could not probe. With microwaves, details of nature are seen that escape kilometer waves. Particles with energies of several hundred million volts resolve nuclear phenomena that exhibit no detail at lower energy. The storehouse of nature, once a simple structure, is now revealed as a vast edifice of ever-lengthening corridors adjoining more and more intricate inner chambers. The translation of these complexities of nature into the service of mankind is an important industrial function which employs all the subdivisions of professional specialization lying between exploratory fundamental research and production engineering.

The path from a complex new discovery to practical utility is frequently long and distressingly expensive. Bringing nylon to market is vastly more difficult than bringing cotton or wool to market. Crawford H. Greenewalt, of Du Pont, has stated that ten years and $27,000,000 were required to accomplish this particular modern miracle. The accumulated costs, as an index of scientific and engineering effort, that have gone into the development of television (which I hesitate to call a modern miracle) have probably not been computed, but the total certainly would be staggering. One need hardly mention the cost and complexity of bringing some of the military developments, especially those in the atomic field, to practical utility. The two-billion-dollar cost of the first atomic bomb is familiar to everyone. The continuing cost of bringing out improved yearly models accounts for an appreciable fraction of the acute sensation of pain annually experienced by our citizenry on March 15. Hundreds of millions of dollars have already been spent in developing atomic fission as a source of power, but certainly a billion dollars will be spent before economical atomic power plants are built. Fortunately, the military applications of uneconomical nuclear reactors are important, and their development will help to pay the bill. I mention these examples—and many more could be cited—of the great cost and complexity of important modern developments of science and engineering. There are undoubtedly modern developments of science and technology that are simple in concept and in translation to practical use, but they are not numerous, and they will be more rare in the future.

The Scientist and the Engineer in Modern Technology

Let us examine some of the consequences to science and engineering that result from this technological complexity. For example, Does the overwhelming weight of planned programs of research mean that exploratory fundamental research has disappeared? I think not. The fact that vastly greater funds flow into the area of applied science does not impress me as evidence to the contrary. I think it is true that fundamental science has never before been so well supported. Although nuclear research is an exception, the fundamental research stage of the technological process is generally not an expensive one, at least not in comparison to the applied research and engineering development that may follow. Hence, in this area, a small amount of money goes a long way. In spite of the great cost of fundamental nuclear research, vast sums have been made available for this work by the Atomic Energy Commission. The enlightened policies of the Office of Naval Research and the recently established National Science Foundation are designed to encourage fundamental science, and they actually do provide generous financial support. Industry is supporting fundamental research to an ever-increasing degree, partly in its own laboratories and partly under university auspices. If truly worthwhile research proposals cannot obtain support under present circumstances, the sponsors must be remarkably inept in presenting their case.

How about the individual scientist in this age of cyclotrons, synchrotrons, supersonic wind tunnels, and atomic proving grounds: Is it forever his fate to submerge his individuality into a background of programmed research projects? To the extent that he works with expensive research tools, this is likely to be the case. If a scientist spends ten million dollars building a particle accelerator, even discounting the probable source of the money, he must not expect to find its research use to be a

contemplative solitary endeavor. The mad, three-shift confusion that surrounds some of these machines creates quite a different impression. Fortunately, not all of modern science is paced by million-dollar machines. The study of the solid state of matter is a notable example of a field of research of the very greatest importance, which has not yet developed the expensive tools and inconvenient trappings of atom-smashing. Here, outstanding progress is being made by individual researchers and small scientific investigation teams.

In modern technology, at what point does science stop and engineering begin? In the early days of industry, when the two were quite separate, this question was easily answered. At present, both scientists and engineers man the numerous stations along the stream of technical progress. At the end nearest to design and manufacture, it is mostly staffed by engineers; at the other end, where the laboratories are located, the scientists predominate; in between, the professional groups intermingle, depend upon each other's technical contribution, and may be difficult to distinguish professionally.

What is the impact of modern fundamental science upon engineering training and practice? Time was—and it was an earlier time—when the engineer could assimilate, during formal engineering training, a codified set of the laws of natural science which provided the tools for a career in engineering practice. This traditional idea of stored technical knowledge sufficing for a professional career is fast becoming obsolete, not only in engineering but in many other fields. To be sure, the old rules are still true and still fundamental, but science has been adding to the rule book, so to speak, and the new editions, with appendices, come out so frequently that it is difficult to follow the game. Consequently, engineering is becoming more complex and more specialized, as new subject matter is added at an ever-increasing pace. The engineer who stays in practice finds it more difficult than ever before to remain current in his technical knowledge, particularly if he is isolated from research laboratories and development laboratories. The technical societies play an ever more important role in bringing to their membership the latest information concerning new developments. It seems to me, however, that a more direct attack on this important problem clearly is necessary. We must recognize the need of replenishing and renewing knowledge as a consequence of rapid technological progress. Perhaps college refresher courses in the latest engineering developments would make it possible for the practicing engineer to augment his fund of specialized knowledge. In any event, it is clear that occasional technical reading will no longer suffice for this purpose.

The scientists who are causing all this trouble are, in turn, in a similar plight. A good scientist, of course, keeps up with the scientific literature, at least in his field of specialization. That could formerly be accomplished by occasionally reading the technical journals in question. But the journals have multiplied in specialization and have become much thicker. Even the abstracts journals in some fields, especially chemistry, have become so thick that there is a need for an abstracts journal to abstract the abstracts journals. If a research scientist were really conscientious about his reading, his research project would start and end in the library, for it would take all his time to read what others are doing in the field in which he intends to work.

Is the engineer subject to more regimentation as a result of the increasing complexity of engineering practice? I think the contrary is likely to be the case. It is undoubtedly true that the efficient pursuit of large research-and-development projects—for example, the development of a nuclear reactor—requires a high degree of coordination of the many technical skills that must contribute to the final result. However, the extensive variety of technical skills employed by modern industry provides, as a corollary, a broad selection from which an individual may choose his field of specialization. Thus, a great range of individual interests may be accommodated within the confines of large coordinated project activity.

What is the saturation point for scientific and engineering manpower in industry, and when will it be reached? Consider the following figures. U. S. industry in the year 1900 employed, on the average, one engineer for every 250 employees. In General Electric at present there is one engineer for every 20 employees. The number of chemists in U. S. industry has doubled in the past fifteen years, and the number of physicists has doubled in the past eight years. Another interesting index is provided by the tabulation of the number of companies which recruit at the colleges. In 1916 only 12 companies did so. By 1929 this had risen to 750 companies; by 1942 the number was 1500; and during 1952, 5200 companies recruited at the colleges. I see no indication that this clear trend in the employment of trained people for the development of industrial technology will not continue long into the future. *Technology is based on science, and science seems to be boundless.* Con-

tinuing research will undoubtedly lead to new developments in science that will lead to new applications to engineering. This technological process appears to be an inexhaustible natural resource.

Some New Technologies

The relationships I have been discussing between fundamental science and engineering will perhaps be clearer if I cite some examples of important and rapidly developing technologies. Many cases come to mind, but a particularly good example is provided by recent research in the field of solid-state physics, where spectacular progress has been made in understanding some of the detailed electrical and mechanical behavior of matter, and where equally spectacular and important progress is being made in the application of the knowledge to practice. The semiconducting elements, of which silicon and germanium are important examples, have provided the best foil for the attack on the electrical properties of solids. Here theory preceded practice (the converse is generally true), and it was only with the discovery of means of drastically purifying the semiconducting materials that theoretically predicted properties were realized. Chemically pure germanium may be hopelessly contaminated, since one part of boron, as a typical impurity, in 100 million parts of germanium will double its electrical conductivity. Skillful experimenters finally discovered means of reducing the impurities in germanium to one part per billion.

Figure 1 shows a laboratory setup for producing pure germanium, and Figure 2 shows an ingot of high-purity germanium which has been made in this furnace. Fortunately, this sample is sufficiently pure to satisfy even the theoretical physicists, who never really expected that anyone would be able to make germanium as pure as they had specified. After we went to all this expensive trouble, the theoreticians said that they did not really want pure germanium after all, but that they wanted to put in their own impurities; and they were particularly partial to indium and antimony. If you put an occasional antimony atom in the germanium crystal lattice, where it fits nicely, the valence electron is surplus and it becomes a conducting electron. Or you may put an occasional indium atom in the germanium lattice. In this case, the *lack of an electron* leaves a sort of "hole" which moves like a positive charge, much like a bubble (which is an absence of something) moves through a liquid.

To make a long story short, if you put some

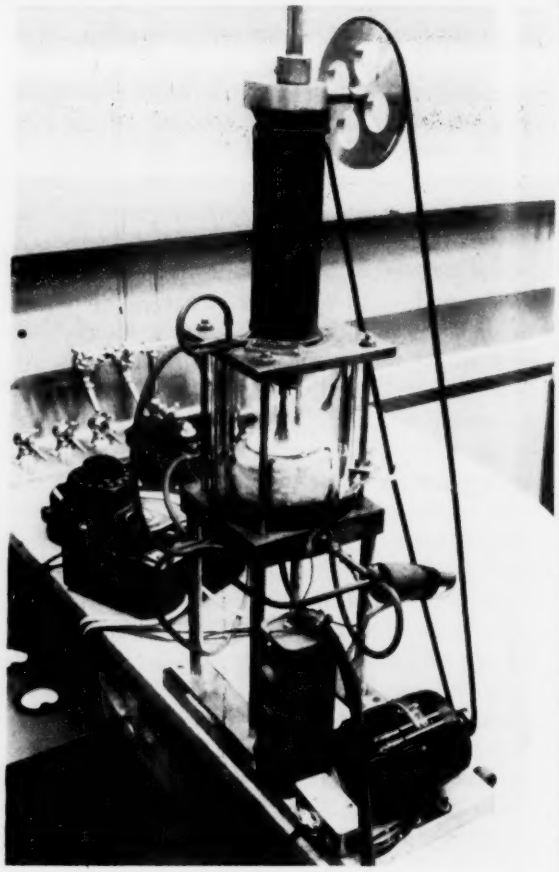


FIG. 1. Laboratory apparatus for producing high-purity germanium.

antimony-germanium in contact with some indium-germanium the result is a rectifying junction. This in itself is not remarkable because there are other rectifying junctions—for example, copper-copper oxide. But the germanium junction *is* remarkable because: (*a*) people can understand why it rectifies; and (*b*) it is an almost perfect rectifier, passing a very high current in one direction and almost none in the reverse direction. This has been a wonderful thing for the theoretical physicists, because it worked out just as they had said it would; but it has been a wonderful thing in many other respects, too, for the phenomenon of semiconductors is adding a new dimension to industrial technology. For example, rectifiers made on this principle are very efficient for use in high-frequency electronics circuits, where they are known as germanium diodes. One such rectifier is shown in Figure 3. Or, they may be made for real industrial power purposes, where their high efficiency makes possible rectifiers of very small size capable of carrying hundreds of amperes of current; one is shown in this picture. The Bell Telephone Lab-

oratories discovered, a few years ago, how to put the equivalent of the control electrode of a vacuum tube into a semiconductor, thus making power amplification possible in a device called a transistor. Although these transistors were originally thought of as low-power devices suitable only for electronics circuits, we have made a transistor recently for high-power applications. Robert Hall, who accomplished this result, is shown with one of these units in Figure 4. In the span of a few years, there have come from this hitherto neglected field of semiconductors a flood of new technical capabilities which have already developed great importance, and which will in the future exert a profound influence upon electrical technology. The particular capabilities I have mentioned, embodied in practical devices for controlling electric power, are certain to have important implications in industry. But it would be a mistake not to recognize that the real significance in this development resides in the fundamental understanding that has been achieved in the basically important field of the solid state of matter.

In the hands of metallurgists, the study of the solid state is yielding new knowledge that is destined to have a correspondingly important bearing on mechanical technology. The strength of materials, especially of metals and alloys, is a primary limitation on the capabilities of the vast galaxy of machines that pace modern civilization. The speed of a motor, the power of an engine, the efficiency of a turbine, the endurance of an airplane, and the vital properties of a host of mechanical things all depend on, and are limited by, the properties of the metallic materials of construction. Without exception, these metals and alloys are crystalline solids, and the problem of improving and extending their properties reduces, in its most basic form, to the problem of understanding the mechanics of crystals. Until recently, attempts in this direction have been frustrating. Figure 5 shows the crystalline character of two ingots of aluminum. There is no doubt that a crystal is a regular three-dimensional array of atoms, and, from a knowledge of the atoms and their arrangement, it should be possible to deduce simple mechanical properties. The density of a crystal is, of course, correctly calculated from the known atomic weight of the constituent atoms and their arrangement, but that is about all that the theory of crystals does for the mechanical properties of solids. If one attempts to calculate the tensile strength of a crystal from this simple picture of atoms in regular array, the calculated result differs widely from the

FIG. 2. Robert Hall, specialist in semiconductors, and Saul Dushman, formerly associate director of the G-E Research Laboratory, examining an ingot of purified germanium.

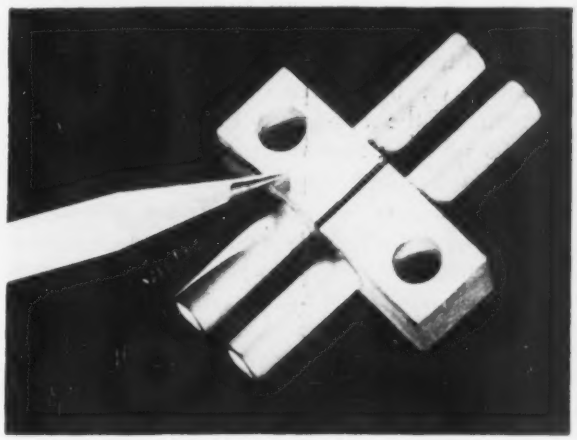


FIG. 3. Air-cooled germanium rectifier.

FIG. 4. Robert Hall and two germanium rectifiers designed and built by him.

FIG. 5. Comparison of two ingots of aluminum, showing difference in crystal structure.

measured tensile strength. This is shown in Figure 6, where on the extreme right the theoretical strength of the aluminum crystal is shown as 600,000 psi. You may see that pure aluminum in practice attains only approximately one hundredth of this calculated value, whereas the best aluminum alloys are only about one tenth as strong as the calculated strength of a perfect crystal of pure aluminum. There are similar difficulties in interpreting other practical properties of crystals in terms of perfect crystal structure. Measured rates of diffusion, rates of solution, rates of crystallization, and rates of phase change, for example, all very important in metallurgy, defy interpretation on the classical basis of crystalline regularity. The key to these problems of great theoretical and practical importance lies in the defects of crystals. Everyone has known for a long time that crystals are generally not perfect, but it now appears questionable whether any example of a perfect crystal has ever been seen, at any time, by anyone! Hence it is not the geometric perfection of crystals, but their invariable imperfections, which determine the practical properties of crystalline solids such as metals and alloys. Concentrated study of the detailed nature of these defects is now revealing for the first time the fundamental nature of the properties of the materials upon which our mechanical civilization rests. A beautiful example of the role of the crystal defect is shown by the growth of crystals from a saturated solution. A perfect crystal would grow very slowly indeed, because the perfect plane crystal faces are atomically smooth, and hence resist the attachment of an atom from the solution. Practical crystals are, however, full of defects and structure discontinuities, in the neighborhood of which almost all the phenomena of crystal growth occur. These growth phenomena have been observed under the microscope, and have even been photographed in motion pictures. Such motion pictures illustrate in a graphic way the crystal growth associated with a stepped, or screw, dislocation. This particular dislocation appears to be a very important one in many practical cases. The geometry of the stepped-wedge dislocation is illustrated schematically in Figure 7. Consider a perfect cubic crystal in the shape of a perfect cube. Make a cut into one face parallel to the cube edge and halfway through the crystal. Then displace the layers of the crystal planes on one side of the cut, relative to the layers on the other side (Fig. 7). As compared to the atomically smooth faces of the crystal, the wedge dislocation is a highly preferred area for growth phenomena to occur. Once this was realized, scientists all over the world discovered spiral growth patterns arising from wedge dislocations in a great variety of crystalline materials. Crystals of silicon carbide that had been in the Mineralogy Department of the British Museum for many years were found recently to exhibit beautiful spiral growth patterns. The stepped dislocations that lead to this phenomenon presumably arise in nature from a variety of causes—impurities, strains resulting from temperature and concentration gradients, and the like. A dislocation of only one lattice parameter could not be seen in the microscope; presumably a single-layer stepped dislocation leads to the

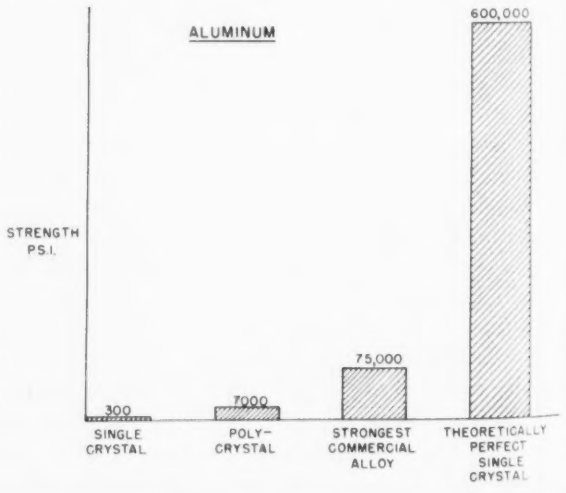


FIG. 6. Comparison of tensile strengths of crystalline materials compared with theoretical value.

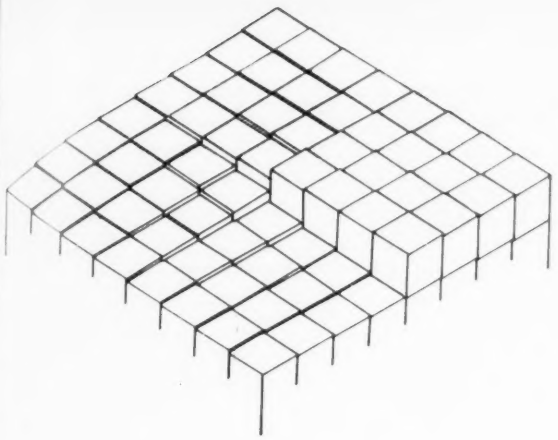


FIG. 7. Schematic illustration of stepped-wedge, or "screw," dislocation.

multiple layer steps that *are* readily visible. Some particularly beautiful growth patterns are seen on the surface of crystals of silicon carbide, as illustrated in the frontispiece. Different colors are seen through the microscope. These are presumed to be due to a surface oxidation film.

The importance of crystal dislocations is of course not confined to the growth of a crystal from solution. Far greater importance attaches to the generalization which logically proceeds from this particular observation. *The practical properties of crystalline solids reside in their lattice defects, not in their crystalline regularity.* This important fundamental observation is a vital key to future progress in the mechanical properties of solids. Both science and engineering will share in the capability, the responsibility, and the satisfaction of translating such knowledge into terms of human welfare.

ATOMIC SCIENTIST

He looked at us with a half-smile,
And listened calmly as we fussed.
He was the gentlest there, the while
He took the questions that we thrust.

"Now that you've given us the bomb,"
A student said, "what move is next?"
The easy smile curled slowly from
His lips . . . His words were not perplexed:

"Why, nothing. No, nothing at all.
All we can do is sit and wait."
Our disappointment was a wall—
But what did we anticipate?

"Live with your work," he said. "Just live,
And let the future slowly come.
We work and dream, we take and give,
And listen to the news at home."

We left him with his patient air
As one aware of what he said.
We went outdoors to mutely stare
At all the future overhead.

DANIEL SMYTHE

Schenectady, New York

Information Processing in Social and Industrial Research*

JAMES L. McPHERSON, SAMUEL N. ALEXANDER, H. BURKE HORTON, and EZRA GLASER

James L. McPherson served as tabulation expert for the 1940 Census of Population and Housing. Since 1943 he has been machine development officer of the Bureau of the Census. Samuel N. Alexander is chief of the Electronic Computer Section of the National Bureau of Standards. Dr. Alexander built the Standards Eastern Automatic Computer, and it is operated at NBS under his supervision. H. Burke Horton was a statistician with the Bureau of Transport Economics and Statistics of the Interstate Commerce Commission during 1945–50. Since October 1950 he has been chief of the U. S. Air Force Interindustry Research Office. Ezra Glaser served in several federal government agencies as an economic statistician and since 1945 has been with the Office of Statistical Standards of the Bureau of the Budget.

I. Electronic Computing Equipment as a New Industrial Tool

LARGE-SCALE electronic machines are capable of processing data for many different applications at very high speeds. These devices are the most recent effort of man to provide a mechanism able to handle arithmetic and logical operations much faster than the human brain, the accountant's pencil, or the desk adding machine. Automatic data computers are not new; what is new and potentially revolutionary is the technology that makes reliable, high-speed, large-capacity data processors operationally effective.

Eight or more general-purpose machines are in operation today, and others will be operating in the near future. The basic components of SEAC (Standards Eastern Automatic Computer) and other large-scale digital computers are the memory, the control unit, the arithmetic unit, and facilities for communicating with the outside world—the input and output units. The most powerful performance characteristics of these devices are their ability to modify the detailed instructions which control the solution of a problem and their selective sequencing ability.

* Based on papers presented at the session of the National Academy of Economics and Political Science at the 119th Annual Meeting of the AAAS, St. Louis, Missouri, December 26–31, 1952.

Table 1 illustrates how such devices are controlled. The 15 digits at memory position 101 are understood to say, "Add the number in memory position 200 to that in position 300, put the sum in 400, and look in 102 for your next instruction." At position 102 is an instruction through which a transfer of control is accomplished. It says, in effect, "If the contents of memory position 101 are the same as the contents of 160, go to 103 for the next instruction, but if the contents of 101 and 160 are not the same go to 106 for the next instruction." When control goes to 106, Operand A is the contents of 101 to which the contents of 180 are to be added. The sum is then placed in 101, which will now read, "Add 201, 301, 401, 102." The machine will proceed through the cycle, 101 to 102 to 106 to 101 to 102 to 106 . . . , etc., until 101 finally reads, "Add 299, 399, 499, 102," which is the same as the constant in memory position 160. At that point control will go from 102 to 103, where it will find instructions for other parts of the problem.

Table 1 illustrates how information stored in the memory can act as an instruction when it is transmitted to the control unit and can be treated as a number when transmitted to the arithmetic unit. This ability, combined with the ability to choose which sequence of instructions to execute, which was typified by the *Equ* instruction, makes possible routines of instructions to govern long and involved

data-handling processes by a series of simple steps.

Since electronic data-processing devices execute instructions at rates of 1000 or more per second, it is obvious that they will be important new tools for our economy. But the significant question is, By whom and how soon will they be introduced? Based on practical working experience with such machines, it may be expected that extensive use of electronic digital data-processing equipment will be made by commerce and industry in a time scale of years rather than decades.

A clerk equipped with pencil and paper is a "general-purpose data-processing" facility. The clerk is much more versatile and intelligent than the SEAC, but the SEAC is infinitely faster than the clerk at doing the relatively few things the SEAC can do. The SEAC can carry out arithmetic processes, it can compare two numbers, and it can choose between next instructions wherever the logical rules can be reduced to simple yes-or-no propositions.

One important characteristic the clerk and the SEAC have in common: until instructed in what to do neither is useful in any specific data-processing situation. To use an electronic digital data-processing device, it is necessary to know what operations the device is capable of performing. When directing the activity of clerks one must have an awareness of the clerks' abilities. Communication with them in a language they understand is essential. A much more fundamental requirement, however, is an understanding of what is to be accomplished in the specific sense. There are comparatively few people today who understand both the real end objectives of many data-processing activities and the mechanics employed to achieve those ends. It is precisely that kind of knowledge which is essential to economically successful use of these new devices. The electronic scientists and engineers have provided the devices. Now those with the jobs these devices can handle must contribute their detailed knowledge of specific problems in order to make use of the new tools.

It is, perhaps, somewhat unfortunate that in the popular press and elsewhere these information processors have been called giant brains. This term tends to make them appear forbidding and difficult to master. They are complicated, ingeniously designed tools intended to free the brains of men by taking over certain routine and repetitive operations. And, like any other tool, they can be useful when properly managed, as aids to achieve prestated objectives. It is remarkable to be able to communicate with an inanimate machine in much the same way that one communicates with a clerk; it is not particularly difficult once one knows the language the information processor understands. The skill with which the device solves a problem is a direct reflection of the intelligence that has been transferred into its operation by the human beings who plan its use. That this can be done seems achievement enough, and it is not necessary to claim the attributes of a brain for such devices.

Distinctions between the "whats" and the "hows" of data-processing activities can be illustrated by census undertakings. The "what" in any given investigation can be described by displaying the schedule used to collect information and the material published presenting that information in organized tabular form. The "how" for such an in-

TABLE 1

ILLUSTRATIVE SEQUENCE OF COMPUTER INSTRUCTIONS

	Memory Location	Operation (3 digits)	Operand A (3 digits)	Operand B (3 digits)	Result (3 digits)	Next Instruction (3 digits)
	101	Add	200	300	400	102
	102	Equ*	101	160	103	106
Instructions	.					
	.					
	106	Add	101	180	101	101
	.					
	.					
	160	Add	299	399	499	102
Constants	.					
	.					
	180	000	001	001	001	000

* Equ = "test for equality." If Operand A is equal to Operand B, get next instruction from memory position shown under "Result;" if not, get next instruction from memory position shown under "Next instruction."

vestigation involves lengthy description. All the instructions to enumerators, respondents, editing clerks, coding clerks, and the other types of employees used in conducting a census investigation are part of the "how" of doing the task in question. The "how" is the complex part of many undertakings. Frequently, the beginning and the end objectives are easy to describe. But interested persons responsible for controlling inventories have discussed the potential use of electronic data-processing equipment. These persons know both the "what" and the "how" of the inventory control problem. They realize that the new equipment might change the "how" very materially, but that it would not alter the end objective, which has been and still is: "Have the right thing at the right place at the right time."

Unfortunately, some data-processing activities have become so compartmentalized that experts in intermediate processes often are really not familiar with either the originating transaction or the ultimate objectives. The employee in charge of the files in any large activity is likely to be an individual with specialized knowledge of how to classify and pigeonhole a variety of documents so they may be found at some unpredictable future time, but with no knowledge of how the papers handled originate or how the product to which they relate functions.

Such an employee might find it quite difficult to accept a system that did not require any removal of documents from the files. Yet such a system is perfectly feasible in the utilization of some of the techniques of the electrical communications field, which provide the means for transmitting and storing information. And electronic computer developments provide means for processing information. Together, a combination is made that has a great future potential. Consider a new system of filing that would employ magnetic recording on automatic playback devices. Telegraphic communication could be established to enable the users to "dial the file" for information, in much the same way that the telephone is now used to find out the time or the weather. Some of the advantages of such automatic files might be: (1) less space required for filing documents; (2) automatic reference to the file; (3) reference to the file without removing the original data; (4) records kept in bombproof underground vaults could be used and kept current; (5) magnetic records could be used which would be more durable than paper or microfilm and more resistant to both water and fire damage; and (6) files arranged so that they would not yield information until a key code word had been supplied, or all the confidential information stored in a scrambled form and an information processor used to decode the information for people authorized to interrogate the files.

The foregoing concerning inventory control and automatic files indicates two areas of potential applicability of these devices. They are by no means the only present possibilities. Any activity that involves a significant amount of clerical work is one on which information processors may have an important impact. Broad knowledge, wide vision, and bold imagination will be needed to harness the new devices to the tremendous loads of paper shuffled every day. There is in sight a clerical revolution that could match the Industrial Revolution. The Industrial Revolution consisted in large part of finding new, standardized, and automatized ways of handling material things. The revolution of today and of tomorrow encompasses the automatization of methods to handle information, and this in turn should generate still better or faster ways to handle things—whether in the automatic factory, or the automatic file, or the control of plane traffic in and out of a busy airport. The tools are ready. Now the persons who have the jobs to be done must contribute their part.

II. Some Uses of Interindustry Statistical Techniques

Interindustry analytical procedures show considerable promise as a means of attacking many types of economic problems. In the Department of Defense improved methods for testing the feasibility of its programs have grown steadily—during World War II and subsequent years. The old-style adamant insistence on military "requirements," which must be met at all costs, has given way at all echelons to a healthy respect for the limitations imposed by the nation's industrial and natural resources. This increased emphasis upon consideration of the nation's capabilities has, in large measure, evolved from the too-frequent adjustment and hasty alteration of plans that occurred during the period 1942–45.

To a great extent past difficulties have been due to inadequate means of measuring and taking account of the goods and services needed *indirectly* in the course of carrying out a war plan. The greatest single advantage of the interindustry technique is that it provides a systematic framework for taking account of all requirements, direct and indirect. A large part of previous mobilization difficulties resulted from attempts to carry out an initially impractical program. In effect, the nation's productive apparatus was used as a gigantic analog

computer to test, ex post facto, the feasibility of a whole series of programs. The answers took the form of insuperable production difficulties, time delays, and constantly changing delivery schedules, rather than "red lights on a control panel." Such a "computation" by trial and error could easily cost the nation more time than it can spare in the event of a new emergency. The present objective is to remove at least a part of this trial-and-error process from the nation's industrial establishments and to place it instead in the computation laboratories.

The broad outline of a procedure for representing the industries of the nation by means of systems of equations has been completed. Modern electronic computers, specifically the SEAC and the UNIVAC,† have demonstrated that they can handle the simplified mathematical systems that can be based upon data now available. These structures are very coarse approximations to the nation's intricate productive systems. Their validity depends upon the persistence of past production techniques and the ability to foresee and incorporate the more important departures from past interindustry relationships.

Computational structures must be sufficiently reliable so that grossly unworkable plans can be detected and modified prior to initiation. The production processes will then run more smoothly, greater reliance can be placed upon decentralized operational control by private management, and the governmental control apparatus can be streamlined and held down to the very minimum necessary under mobilization conditions. The procedures now being perfected are advance forecasting tools —not operational control devices.

The mathematical structures, or "models," now being used, are the result of a marriage of linear programming techniques, as applied to internal Air Force activities,[1] and the "input-output," or interindustry, techniques of economic analysis originally developed by Wassily Leontief, of Harvard University,[2] and developed further by staff members of the Bureau of Labor Statistics, U. S. Department of Labor.[3] The principal ingredient in the mathematical model is a set of functions which express in quantitative terms the relationship between the output of each industry and its requirements for the products of other industries on current account. The analytical procedures handle in separate and distinct stages current account purchases, needed to support production without increase in capacity, and capital account purchases required to increase capacity.

The Division of Interindustry Economics, Bureau of Labor Statistics, U. S. Department of Labor, was given the task of assembling the first postwar interindustry transactions table. This table was based upon the 1947 Census of Manufactures, the 1948 Census of Business, and a variety of supplementary sources. The basic study was carried out in 450-industry detail, with supporting product analyses for many industries. The Standard Industrial Classification, by which each establishment is assigned to an industrial class according to its principal product, was adopted as the basic classification. The heterogeneity of the output of many industrial sectors and the lack of acceptable physical measures of output in such instances led to the adoption of dollar sales (or purchases) as the principal unit of output (or consumption).

For computation purposes the 450-industry table was condensed to 190 industrial sectors. Table 2, an extract from this condensed table, indicates, for example, that the Motor Vehicle industry purchased $36.4 million of Electric Power in 1947. The Electric Power industry in turn purchased $7.5 million of Motor Vehicle products in 1947; this was in addition to capital outlays for complete new vehicles.

The limited amount of information now available for any one cell of this table precludes the use of elaborate functions relating consumption to output. If it is assumed that inputs, or purchases for current account, are proportional to output, a set of coefficients can be obtained (Table 3). This table shows, for example, that if sales and purchases (measured at 1947 price levels) vary proportionately, $76,986 of Electric Power is required to produce $1,000,000 of Primary Aluminum.‡ The network of industrial interrelationships is so complex that the output required of each industry for any given final demand can be determined only by summing an infinite set of values. It can be shown, however, that the sum is finite.

If A denotes the matrix of coefficients from which

† UNIVersal Automatic Computer, produced by the Eckert-Mauchly Division of the Remington Rand Corporation. UNIVAC No. 2 was accepted by the U. S. Air Force on June 25, 1952, and operates in the Pentagon 24 hours per day, 7 days per week. The Mathematical Computation Branch of the Planning Research Division is responsible for its operation.

‡ Linear nonproportional relationships can be handled with ease by present computing equipment. Such linear relationships can frequently be used over a wide range of values to give a satisfactory approximation to a more complicated function. Insufficient data are available in most cases, however, to serve as a basis for altering the assumed proportional relationships.

TABLE 2

EXTRACT FROM TABLE 1,* INTERINDUSTRY FLOW OF GOODS AND SERVICES BY INDUSTRY OF ORIGIN AND DESTINATION†

Continental United States, 1947

(Millions of Dollars)

Sector No.	Industrial Sector	4	16	49	58	88	127	145	148	167	169	Final Demand‡	Gross Domestic Output
4	Food Grains and Feed Crops	816.7	0	25.3	0	0	0	0	0	0	0	61.8	11,004.2
16	Coal Mining	0	14.6	17.2	0.2	0.3	0.4	14.9	0.9	384.6	408.1	444.0	3,036.4
49	Industrial Organic Chemicals	4.6	0	264.2	2.7	0	0	9.0	0	1.3	0.1	210.6	1,672.3
58	Fertilizers	245.7	0	1.0	60.6	0	0	0	0	§	0	18.4	522.8
88	Primary Aluminum	0	0	0	0	0	0	0	0	0	0	−16.3‖	284.6
127	Ball and Roller Bearings	0	0	0	0	0	16.8	104.8	5.9		1.5	44.4	387.0
145	Motor Vehicles	58.3	15.2	0	0	0	0	3,294.0	22.2	7.5	0.2	7,385.4	12,519.7
148	Aircraft	0	0	0	0	0	0	16.7	143.0	0	0	1,363.8	1,604.9
167	Electric Light and Power	5.5	55.6	18.7	3.3	21.9	3.6	36.4	10.2	395.5	28.3	294.7	4,436.5
169	Railroads	117.1	6.0	40.9	46.7	3.9	3.7	237.2	11.6	127.6	411.5	4,689.2	9,959.0

* Source: U. S. Dept. Labor, Bur. Labor Statistics, Div. Interindustry Economics (Oct. 1952).

† Each row shows distribution of output of producing industry named at left. Each column shows input distribution for purchasing industry named at top.

‡ Final Demand is the consolidation of Households, Inventory Change, Gross Private Capital Formation, Government, Foreign Trade, Construction, Stockpile, Waste Products, Small Arms, and Small Arms Ammunition.

§ Less than $50 thousand.

‖ Very little Primary Aluminum enters into Final Demand. Most of the output is used as an intermediate product. A decrease in inventory in 1947 and some imports (negative Final Demand) account for the minus sign.

Table 3 is extracted, the "inverse complement of *A*" [or, symbolically, $(I\text{-}A)^{-1}$] is a matrix of factors which makes possible the direct calculation of such sums. Table 4 is an extract from the 190-order inverse complement of *A*.§ Granting the basic assumptions, Table 4 points out that orders of consumers for $1,000,000 of Motor Vehicles generates the following outputs by other industries: Railroads, $52,376; Electric Light and Power, $15,867; and Coal Mining, $15,515, as indicated in Column 145. The row for each industry contains a set of factors that measure the given industry's stake in the consumption of products of all other industries For example, the Ball and Roller Bearing industry has a stake of $14,100 in an order for $1,000,000 of Motor Vehicles. The production of $1.0 million of motor vehicles for final consumers regenerates *indirect* effects of $1.7 million as measured in terms of plant sales for all industries. Thus, a total of $2.7 million of transactions is required to fill an order for $1.0 million of motor vehicles. This type of table has implications for market analysis, although it was not developed for this purpose.

Timing is of the essence in mobilization forecasting. Table 5 is extracted from a 190-order table of average timing factors prepared from data furnished by the Office of Business Economics, U. S. Department of Commerce. Each factor measures in calendar quarters the average time interval by which the output of goods and services from the industry at the left must precede the output of the industries listed across the top. These factors were estimated primarily from inventory data (reciprocal of turnover rates), with certain additional adjustments. Row 127, Column 145, Table 5, indicates that ball and roller bearings should be delivered to plants of the Motor Vehicle industry an average of 0.9 quarter prior to delivery of a completed automobile or truck. For computation purposes integral lead times are desirable. The associated input coefficient is split, therefore, 9:1. The first portion is assigned an input lead time of 1.0 quarter, and the second portion receives a lead time of 0.0 quarter, thereby preserving the average lead time of 0.9 quarter.

The use of integral lead times changes a time-phased model to the same form as a very large static model. If there are 190 industries and 16 time periods (4 years, by quarters) plus a 17th

§ The inversion of this 190-order matrix was one of the largest integrated mathematical operations ever successfully completed. It involved about 7,000,000 accurate multiplications of 9-digit numbers. This task was done in less than 50 hours. Air Force and Eckert-Mauchly personnel worked jointly to complete the operation, using the UNIVAC No. 1 of the Bureau of the Census in Philadelphia. Several such large-scale inversions have since been performed on the Air Force UNIVAC in the Pentagon.

TABLE 3

EXTRACT FROM TABLE 2,* DIRECT PURCHASES PER MILLION DOLLARS OF OUTPUT†

Continental United States, 1947

Sector No.	Industrial Sector	4	16	49	58	88	127	145	148	167	169
4	Food Grains and Feed Crops	74,216	0	15,143	0	0	0	0	0	0	0
16	Coal Mining	0	4,821	10,268	430	994	977	1,190	581	86,684	40,978
49	Industrial Organic Chemicals	421	0	158,725	5,116	0	0	715	0	284	5
58	Fertilizers	22,329	0	608	116,187	0	0	0	0	6	0
88	Primary Aluminum	0	0	0	0	0	0	0	0	0	0
127	Ball and Roller Bearings	0	0	0	0	0	54,896	8,371	3,707	0	150
145	Motor Vehicles	5,300	4,997	0	0	0	0	268,605	13,848	1,682	24
148	Aircraft	0	0	0	0	0	0	1,331	91,473	0	0
167	Electric Light and Power	499	18,319	11,163	6,298	76,986	9,284	2,906	6,329	89,140	2,845
169	Railroads	10,638	1,961	24,449	89,348	13,728	9,473	18,946	7,199	28,758	41,321

* Source: U. S. Dept. Labor, Bur. Labor Statistics, Div. Interindustry Economics (Oct. 1952).

† Each entry shows direct purchases from industry named at left by industry at top per million dollars of output of the latter.

period for "level-off,"‖ then there are 17×190, or 3230 variables, to be computed. This can be handled in the same manner as a 3230×3230 static problem. By taking advantage of certain special characteristics of the system, however, it is possible to reduce this unmanageable method to seventeen 190×190 systems solved in sequence.¶

The results of the first large computation, called the "Emergency Model," are being appraised. This model is based upon 1947 coefficients brought up to date as of about 1951 in important areas. It was found necessary to supplement the listed industries by special analyses of important military end items not in production in 1947. The design of sampling procedures to determine the industrial impact of the host of civilian-type items procured by the three services is a complex task. Before this structure and the computed military requirements could be used, estimates of nonmilitary final demand were found to be needed to round out the complete picture of requirements. These estimates were prepared by governmental agencies outside the Department of Defense.

Analytical tools of the type described above have been developed as part of the Air Force research program in interindustry economics. This program was undertaken at the request of the Department of Defense. Army and Navy personnel are assisting in translating military requirements into the precise form necessary for these mathematical structures. In addition to the projects mentioned above, techniques are being developed for the purpose of translating production schedules into manpower requirements, industry by industry. Other projects, which are well under way, will provide a means for quickly determining the effect of adding new capacity in industries found to be deficient in the course of a computation. The Bureau of the Budget has accepted the task of monitoring the research projects carried on by other governmental agencies and by universities.

If, as a result of this research, any major differences between military requirements and industrial capabilities are brought to light, the program will have been worth while. Corrective action may be taken on both sides of such discrepancies. If urgent military necessities do exceed present or prospective capabilities, it is highly important that the facts be known years in advance, while there is time to take corrective action. If the indicated corrective action itself exceeds the means, then there is a need to review the military necessities. Early review will guard against the haphazard, unbalanced readjustments that will surely occur if an impracticable program is attempted and cutbacks are made in haste. It appears that a substantial portion of these major difficulties can be brought to light by present interindustry analytical procedures. It is highly desirable that this process of review and adjustment take place in the computation laboratory in advance of an emergency, rather than in the nation's factories when it is too late for expansion of indus-

‖ This permits the assumption of continuing production at constant levels for all industries in the postmodel years.

¶ The procedure, suggested by George Suzuki, of the Air Force Interindustry Research Office, takes advantage of the fact that inputs precede outputs. Consequently, if the last time period is solved first, indirect requirements which must be produced in earlier time periods are fixed. The computation proceeds backwards in time, yielding a set of solutions for each time period. This problem was handled by an iterative procedure on the SEAC.

trial capacities or for changes in a balanced program.

III. Formal Programming and Information Processing in Social Science, Accounting, and Management

Questions concerning formal programming and information processing do not fall within any traditional field of study. Rather, they occur near the boundaries or in the overlapping regions of statistics, other and younger branches of applied mathematics, social sciences (especially economics), technology, and management. Certain logical and practical advantages are derived from the circumstance that the analytical framework of interindustry studies constitutes a closed system of information in the sense that some well-defined domain is covered without duplication. This kind of analysis need not be restricted exclusively to economics. It has possible applications elsewhere, in areas where some of the advantages of the approach might carry over to new problems.

In searching for applications of especially constructed routines of information processing in whatever branch of applied science, their course drifts toward the same areas as the two general lines of inquiry in the above separate discussions. Collectively, a useful unit is formed. Without the very high-speed equipment, with its related coding and processing techniques, the formal economic analysis could have realized only a small part of its potential usefulness. Similarly, the equipment is a lost and confused servant without a carefully worked-out set of definitions, classifications, and systems of information processing.

It is useful to follow through the motions of how a general-purpose computer might be used in some specific business unit—for example, a billing office of a department store. For convenience, the operations or activities may be divided into three classes. Into the first go all routine activities. These are operations that require no judgment and that occur frequently. The second class of activities is composed of operations that require judgment. Either there are too many variables influencing the decisions, or their relation to the decision is complicated, or the relevant information is subtle by nature or difficult to find. The third and last class contains atypical items that do not require any particular judgment in the usual sense of needing the attention of a person of superior mental ability and experience. A clerk, for example, can do what is required. This case arises so infrequently, however, that it does not pay to establish a routine for mechanical or electronic handling. The high-speed computer can do the first task—a routine operation. It cannot do the second—that of judgment. It does not pay to have it do the third—the simple but atypical work. An operation classed as atypical might occur more frequently than had been guessed; thus it might be moved into the first class and a new routine established. Some judgment acts in the second class might be reduced to a formal program and placed in the first with a fairly complicated routine.

A case of applying a computer to a complete administrative system, perhaps a department store, can be considered. The interest will not be mainly in the computer, but rather in a rational approach to the processing of information and the programming of activities.

Consider first the domain of financial data—the information in the general accounts. Identify every point where a decision must be made. With each decision point is a set of alternate courses of action—one particular procedure for each decision that can be taken. For routine decisions the procedures will be completely described; for the most complex decisions the procedure might not be determined in advance. The decision points will then be classified into the three classes described above: routine, judgment, atypical. This will provide a tentative split of the operations of the administrative unit into two groups—those performed by machines and those performed by human beings.

The domain of information can be expanded to cover, for example, an inventory-control system. A new list of decision points is catalogued and classified into the three classes. Now, however, there are interactions between the domain added and the original one. New uses for the old data appear, sometimes in combination with new kinds of information. As the domains of information and decision making are extended to, perhaps, production scheduling and control, market analysis, product research, and development, several new factors will appear: (1) new uses for information will evolve; (2) more complex decisions will be listed—those requiring a greater volume of data, or more different kinds of information, or more complicated relationships between the information and the decision; and (3) broader scope of decisions will come under scrutiny—i.e., decisions affecting more parts of the organization or large ranges of products, or longer intervals of time—to the extent that the general type of decision made will be less like that of a file clerk and more like that of a supervisor, or even approaching the function of some minor executive.

In principle, the analysis of information uses

TABLE 4

EXTRACT FROM TABLE 3.* (TRANSPOSED) DIRECT AND INDIRECT REQUIREMENTS PER MILLION DOLLARS OF FINAL DEMAND†

Continental United States, 1947

(Unit: $1000)

Sector No.	Industrial Sector	4	16	49	58	88	127	145	148	167	169
4	Food Grains and Feed Crops	1,086.5	.5	27.3	5.0	1.2	.5	2.7	.8	.3	1.6
16	Coal Mining	7.2	1,009.0	36.2	39.2	25.2	11.8	15.5	7.5	99.0	45.4
49	Industrial Organic Chemicals	3.5	1.9	1,212.3	32.2	22.9	1.8	12.4	3.6	1.4	1.5
58	Fertilizers	28.0	.1	3.5	1,135.7	4.0	.1	.4	.2	‡	.1
88	Primary Aluminum	.1	.6	.7	.7	1,026.1	1.7	4.7	11.4	.1	.7
127	Ball and Roller Bearings	.5	.6	.3	.3	2.2	1,058.9	14.1	5.6	.2	.4
145	Motor Vehicles	13.7	9.0	3.1	3.3	4.2	1.4	1,376.2	23.9	4.3	2.3
148	Aircraft	.1	.1	.1	.1	.1	.1	2.3	1,100.9	‡	.2
167	Electric Light and Power	11.7	22.7	23.1	20.7	100.5	16.8	15.9	14.7	1,101.6	6.3
169	Railroads	21.3	7.7	54.3	136.0	55.0	25.9	52.4	21.1	36.0	1,047.3

* Source: U. S. Dept. Labor, Bur. Labor Statistics, Div. Interindustry Economics (Oct. 1952).

† Each entry shows, per million dollars of deliveries to final demand by industry named at top, total dollar purchases directly and indirectly required from industry named at left.

‡ Less than $50.

and decision making within an administrative unit will eventually produce a catalogue of all possible uses of each piece of information. The initial question, then, of how to use a "feeble-minded" but fast mechanical servant has led to a different question: How can a study of informational domains and informational flows be systematized in relation to decision making and the construction of efficient processing of "paper work"?

Why does a formal study or a formal "science" arise in a case such as this? What is behind the evolution of a new branch of applied mathematics or applied formal logic? When the analysis of a problem demonstrates the need for many distinctions, a classification system is constructed in which there are many classes. When there are too many classes, and their properties are too complex to remember and apply to a problem, and the relationships among them assume a great variety of logical patterns, then it becomes necessary to define formal rules and create formal structures for assembling, analyzing, and using information. This is one of the origins for a new kind of applied science: the theory of information.

At the one extreme decisions are made by "hunch" or an undefined "experience." A maximum of efficiency for any one brain is eventually reached, with only limited opportunity to pass along the knowledge to others and limited opportunity for division of labor in the judgment matters. At the other extreme—and this is of course an extreme position—there is almost no use for "hunch" or personal judgment. Each decision point is defined, and an array of all useful decisions is con-

TABLE 5*

INPUT LEAD TIMES FOR SELECTED INDUSTRIES†

(Unit: 1 quarter)

Sector No.	Industry	4	16	49	58	88	127	145	148	167	169
4	Food Grains and Feed Crops	4.0		0.7							
16	Coal Mining		0.7	0.7	0.7	0.5	1.5	0.9	1.3	1.0	0.5
49	Industrial Organic Chemicals	4.0		0.7	0.7			0.9	1.3	1.0	2.1
58	Fertilizers	4.0		0.7	0.7					1.0	
88	Primary Aluminum								1.3		
127	Ball and Roller Bearings						1.5	0.9	1.3		2.1
145	Motor Vehicles	4.0	0.7					0.9	1.3	1.0	2.1
148	Aircraft and Parts							0.9	1.3		
167	Electric Light and Power	1.9	0.3	0.2	0.2	0.1	0.6	0.3	0.6	0.1	0.1
169	Railroads	3.8	0.6	0.6	0.6	0.4	1.4	0.9	1.3	0.9	1.1

* Source: U. S. Dept. Commerce, Off. Business Economics, Business Structure Div.

† Each entry shows the average time by which the delivery of goods and services of the industry listed at the left must precede the delivery of completed products of the industry listed at the top.

structed. Functional relationships between the information and the decisions are discovered or postulated. The result is a set of logical processes by which many kinds of data can be brought to bear on a problem as though there were some one brain equal to the task of mastering the entire range of data, relationship, and decision.

The application of the principles of formal programming and formal information processing to social science, accounting, and management, then, encounters two difficulties: (1) many data and usually many different kinds of data are needed, and such must be in a particular form with respect to dating, accuracy, classification, units (including price level if the units are in money values), and, perhaps, other matters; and (2) the uses of the data are complex—a decision might profitably take into account more variables than one can bring to mind, and functional relationships in the mathematical sense might be too complicated to grasp without especially devised formal analytical equipment. Frequently, *both* the number of variables and the complexity of relationships dictate the need for a formal framework.

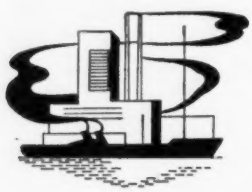
Part I has developed the accounting application of information processing equipment—often called computers. It has attempted to dispense with mental "ditch digging" in keeping accounts, mailing bills, totaling individual records, and filing information and referring to it later when needed for some business operation. The objective is to obtain accurate work at high speed and low cost. This involves simple decision making. As the number of variables increases and the relationships become complex, the direction is away from clerical operations toward management operations, away from the routine processing of information toward the complex.

Part II has discussed a specific application in the social sciences. By earlier standards, this economic analysis required a formidable volume of basic data from many sources. Even if the economic model is restricted to linear relationships, the system of relationships is complex in that every industry is simultaneously affected by the level of production in nearly every other industry. No individual can examine raw tables, study the relationships, and derive approximate results. But after the formal processing has proceeded far enough, then a trained person can derive very useful classes of answers. In this case, however, there is a dependency upon the formal analysis which has already been completed. It does not seem possible to keep account of either the data or the relationships without a formal programming system.

It now appears to be evident that the search for an electronic file clerk is neither unrelated to—nor inconsistent with—an attempt to make major judgments more systematically and with the fullest use of available information and discoverable relationships. In many situations these problems may prove to be complementary in the sense that neither undertaking could be done well by itself.

References

1. Wood, M. K., and Dantzig, G. B. *Econometrica,* 17, 193 (1949); Dantzig, G. B. *Ibid.,* 200.
2. Leontief, W. *The Structure of the American Economy, 1919–1929.* Cambridge: Harvard Univ. Press (1941). Now available in revised form, *The Structure of the American Economy, 1919–1939.* New York: Oxford Univ. Press (1951).
3. Evans, W. D., and Hoffenberg, M. *Rev. Economics and Statistics,* **34**, 97 (1952).



SCIENCE ON THE MARCH

BIOTIC CHANGE IN NEW ZEALAND

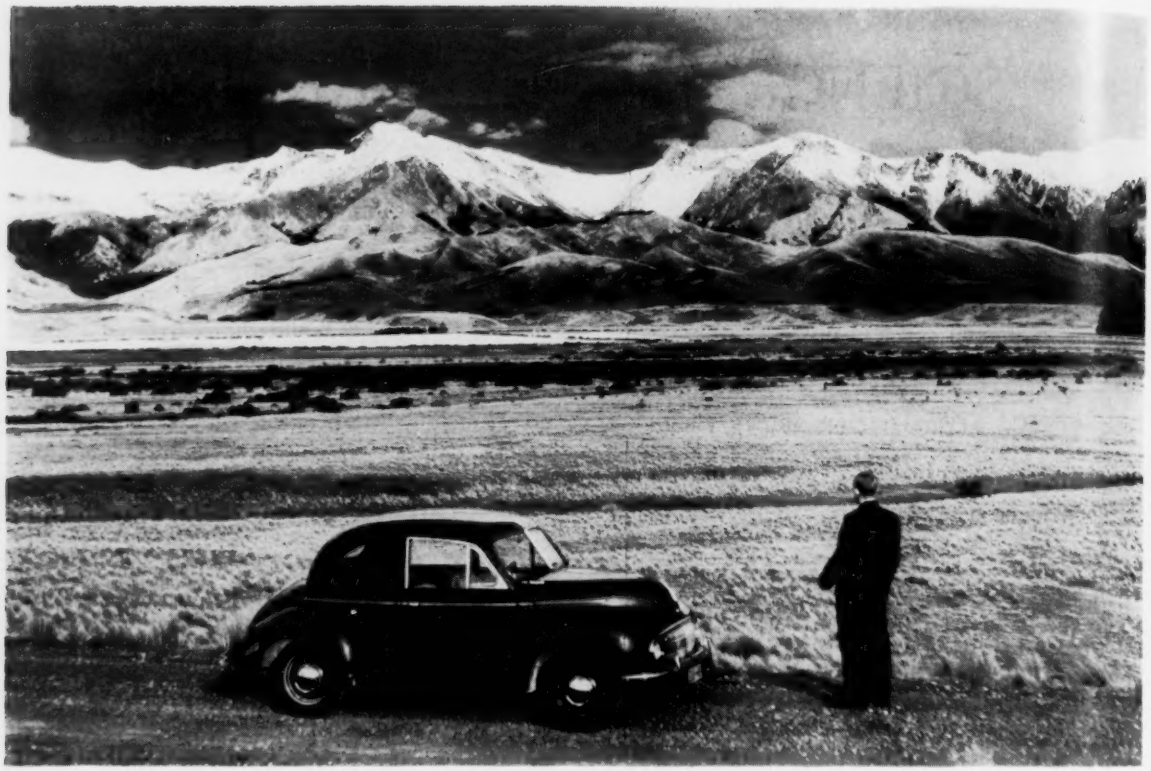
MANY areas recently colonized and developed by Europeans have undergone such rapid and often revolutionary changes in their native vegetation and animal life, and in some of their soil and physiographic conditions, that thorough study should yield valuable information for ecologists, other biologists, and conservationists. Several regions in the temperate zones of the Southern Hemisphere, especially parts of Australia, South Africa, and New Zealand, have passed through some of the most rapid changes in modern times. Of these, New Zealand probably offers the most significant information, because its islands have formed a microcosm to which the changes have been confined. Also, the original conditions were in many ways unique; likewise, many of the changes have been accurately recorded and recently evaluated by geographers and biologists. After a year's visit to New Zealand and a review of the records of its settlement and the induced changes in natural conditions, I was impressed with the numerous ways in which American scientists might benefit from a study of this record, which is not too well known or appreciated in this country.

Four recent publications bear particularly on the subject of induced biotic changes in New Zealand: two by the geographers Cumberland[1] and Clark,[2] and two by the biologists Wodzicki[3] and Murphy.[4] Clark's account of changes in the South Island is a comprehensive study in historical geography, which traces the many facets of change and development, such as the human population, deforestation, crop development, grazing and pasturage, and the effects of the introduction of particular plants and animals. Cumberland shows how slip erosion on steep hills has greatly increased because of overgrazing, changes in the grasses and other vegetation, and frequent fires. Wodzicki discusses the often disastrous effects of the introduction of mammals and other animals, and some plants, which in many cases have become destructive pests. Murphy, in a short but strongly written article, also points out how the introduction of animals has often been a mistake, and he lays much blame for this upon the acclimatization societies, which in their zeal brought in animals and plants without any concern as to how they would fit into the total ecological pattern of the islands.

Clark's historical geography is much the most complete and best documented of these publications. He lists in his bibliography over 500 titles, which cover nearly every phase of change, and in the text he thoroughly considers, among other factors, cattle and sheep grazing, raising of wheat and potatoes, deforestation, and some of the notable cases of the effects of introduced plants and animals that have "gone wild" and overproduced in their new habitat.

The islands—especially the South Island—have such a variety of climates and physiographic conditions that many distinctly different areas occur in close proximity. There are great mountain ranges, such as the Southern Alps, and wide plains, such as the Canterbury Plain. The rainfall varies from about 200 inches a year to as little as 15 inches, within a distance of some fifty miles. Large forests once existed that varied from subtropical types to cold subantarctic types within short distances. Along the mountain ranges and their foothills a particular type of tussock grassland had developed that before settlement had not been grazed or often burned. There were no mammals among the native animals, which consisted mostly of birds. They existed in moderate numbers and in balanced populations, among which there were few predators. Only a few Maori had settled, and these Polynesian people had done little to disturb the intricate balance of nature.

These islands were invaded over a period of several decades, mainly from 1840 to 1900, by Europeans and a few Orientals, who brought with them some 53 different mammals, 125 birds, and numerous plants for the forests and hedges and pastures and crops. The human immigrants did the usual things that upset the balances in nature as they converted former forests to fields and fields to cities. There was intense activity in clearing forests for sheep pasturage, and fires spread far beyond their intended bounds. Following the fires, native plants, notably the manuka, or tea tree, spread and occupied the ground with scrub growth, which, although inferior economically, has served to stabilize the soil and initiate the ultimate return of the forest. Soils overgrazed by merino and



Tussock grasslands and Southern Alps mountains, with scattered, small forests of the southern beech trees, and scrub vegetation in the valley. All three types of vegetation have been greatly altered by man and introduced animals within the past twelve decades.

mixed-breed sheep soon became gullied and eroded on the steep slopes that are so common on both islands. All manner of consequent changes took place, and from the record much can be learned of the particular results of certain practices. But to many ecologists and other biologists the less direct man-induced changes are the most interesting.

The sheep, and to a lesser extent the cattle, were the first grazing animals ever present on the native grasslands, which were in effect as near the climax type as the soil and climate could support. These animals, by their differential choice of forage, their trampling, and other activities, changed the nature of these grasslands even in areas where they were not numerous enough to overgraze. Thus there is a record here of what happens to undisturbed grasslands suddenly exposed to the effects of grazing. New Zealanders have studied these effects, and their records can tell us how certain changes were produced. Such information should be valuable to a better understanding of the past history of the North American grasslands.

The sheep have done their damage to the grasslands, but currently animals are being introduced into the forests and scrub that are more slowly but just as surely changing them. These are mainly deer, goats, and wild pigs introduced from Europe, America, and Asia, and the opossum introduced from Australia. Because of its arboreal habits, the opossum is eating the forests from the top down, and the browsing and grazing hoofed animals are eating the forests from the bottom up. Numerous areas lack a natural growth of seedlings and young trees because of the activity of these animals, and in some areas where the opossum is abundant even the larger trees are being injured or killed in large numbers.

The introduced rabbit has been the worst pest of all in some districts, such as central Otago, and the costly attempts to control it illustrate another mistake made by the acclimatization societies. Certain Musteliadae, especially weasels, were brought in as predators to reduce the population of rodents, and Wodzicki noted evidence of their feeding on birds. One such bird is the very rare Notornis, now living only in a high valley of Fiordland; here the introduced predators must be trapped to near extinction if the small Notornis population is to be preserved.

These are but a few examples of the upset eco-

logical balances among the animals. The plants furnish similar examples. The European gorse, and to some extent the brooms, originally introduced as hedge plants, have spread onto the pastures and over other large areas, taking over valuable pasturage. The brambles of the genus *Rubus* have similarly spread and become an important pest. Indeed it is said that on the South Island west coast there is one blackberry bush, and it is a hundred miles long.

Nostalgia for the homeland, which for the majority of settlers was England or Scotland, prompted the introduction of the gorse, red deer, and certain birds. American introductions were similarly made, and several, such as the Monterey pine, have become valuable acquisitions. But the main difficulty with the zeal of the acclimatization societies, or any other groups making such introductions, has been their lack of ecological foresight. This group of islands, therefore, points up the thesis of many ecologists and conservations: that a knowledge of the multiple physical, climatic, and biotic relations is the proper basis for introductions, planning of change, and management. These multiple relationships are seldom easy to ascertain, but some estimate of them may be gained from studies of those changes of the past related to man's indiscriminate tampering with nature. New Zealand offers an excellent field for such studies.

JOHN H. DAVIS, JR.

Department of Botany
University of Florida

References

1. CUMBERLAND, K. B. *Soil Erosion in New Zealand: A Geographic Reconnaissance.* Wellington, N. Z.: Soil Conservation and Rivers Control Council (1944).
2. CLARK, A. H. *The Invasion of New Zealand by People, Plants and Animals; The South Island.* New Brunswick, N. J.: Rutgers Univ. Press (1949).
3. WODZICKI, K. A. *Introduced Mammals of New Zealand,* Bull. No. 98. Wellington, N. Z.: Dept. Scientific and Industrial Research (1950).
4. MURPHY, R. C. *New Zealand Geographer,* **8**, 1 (1952).

New Books Received

Carbohydrate Metabolism. (Rev. ed.) Samuel Soskin and Rachmiel Levine. x + 346 pp. Illus. $8.50. University of Chicago Press, Chicago. 1952.

An Introduction to the Chemistry of the Hydrides. Dallas T. Hurd. x + 231 pp. $5.50. Wiley, New York; Chapman & Hall, London. 1952.

Storage Tubes and their Basic Principles. M. Knoll and B. Kazan. xiii + 143 pp. $3.00. Wiley, New York; Chapman & Hall, London. 1952.

Maleic Anhydride Derivatives. Reactions of the Double Bond. Lawrence H. Flett and William Howlett Gardner. x + 269 pp. Illus. $6.50. Wiley, New York, 1952.

Wood Chemistry, Vol. 1. (2nd ed.) Louis E. Wise and Edwin C. Jahn, Eds. vii + 688 + xxxii pp. Illus. $15.00. Reinhold, New York. 1952.

Great Barrier Reef Expedition, 1928–29. Scientific Reports, Vol. BI, No. 3., *Madreporaria, Hydrocorallinae, Heliopora and Tubipora.* Cyril Crossland. 257 pp. + 56 plates. £3 10*s.* British Museum (Natural History), London. 1952.

Ink and Paper in the Printing Process. Andries Voet. xii + 213 pp. Illus. $5.90. Interscience, New York. 1952.

Personality in the Making. The Fact-Finding Report of the Midcentury White House Conference on Children and Youth. Helen Leland Witmer and Ruth Kotinsky, Eds. xviii + 454 pp. $4.50. Harper, New York. 1952.

Psychiatry and the Law. Manfred S. Guttmacher and Henry Weihofen. viii + 476 pp. $7.50. Norton, New York. 1952.

Great Adventures in Medicine. Samuel Rapport and Helen Wright, Eds. xxi + 874 pp. $5.00. Dial Press, New York. 1952.

Pasture Production and Management. R. H. Lush. x + 193 pp. Illus. $3.75. Blakiston, New York. 1952.

Limbo. Bernard Wolfe. 438 pp. $3.50. Random House, New York. 1952.

Rheumatic Fever. A Symposium held at the University of Minnesota on Nov. 29, 30, and Dec. 1., 1951, under the sponsorship of the Minnesota Heart Association. Lewis Thomas, Ed. 349 pp. $10.00. University of Minnesota Press, Minneapolis. 1952.

A Physiological Approach to the Lower Animals. J. A. Ramsay. ix + 148 pp. Illus. $2.75. University Press, Cambridge, England. 1952.

Soviet Civilization. Corliss Lamont. xviii + 433 pp. $5.00. Philosophical Library, New York. 1952.

Elementary Analysis. Kenneth O. May. xviii + 633 pp. $5.00. Wiley, New York; Chapman & Hall, London. 1952.

Human Milk. Yield, Proximate Principles and Inorganic Constituents. Technical Communication No. 18 of the Commonwealth Bureau of Animal Nutrition, Rowett Research Institute, Bucksburn, Aberdeenshire, Scotland. S. D. Morrison. viii + 91 pp. Illus. 10*s.* 6*d.* or $1.50. Commonwealth Agricultural Bureaux, Farnham Royal, Slough, Bucks. 1952.

Biological Chemistry. An Introduction to Biochemistry. Alexander Gero. xvi + 340 pp. (No price given.) Blakiston, New York. 1952.

The Indian Tribes of North America. Smithsonian Institution Bureau of American Ethnology Bull. 145. John R. Swanton. vi + 726 pp. + 5 maps. $3.50. GPO, Washington, D. C. 1952.

Introduction to Theoretical Physics. (3rd ed.) Leigh Page. xi + 701 pp. $8.50. Van Nostrand, New York. 1952.

Life and Letters of R. A. F. Penrose, Jr. Helen R. Fairbanks and Charles P. Berkey. x + 765 pp. Illus. Geological Society of America, New York. 1952.

Manual of Photogrammetry. (2nd ed.) xiv + 876 pp. Illus. $9.00, members; $12.50, nonmembers. American Society of Photogrammetry, Washington, D. C. 1952.

BOOK REVIEWS

THEORETICAL PHYSICS

The Theory of Relativity. C. Møller. xii + 388 pp. Illus. $7.00. Oxford University Press, New York, 1952.

ACCORDING to Professor Møller, this book is the result of twenty years of teaching relativity at the University of Copenhagen. It is distinguished by careful attention to the didactic problems presented by the theory and by special emphasis on its "physical"—i.e., intuitive—aspects. At the same time, the presentation is unusually complete and is suitable as a basic text for a year's course which starts at a fairly elementary level but which will, by the year's end, have taken in the major aspects of both the special and the general theory. In writing this book, Møller has had the advice of Niels Bohr, and I believe the book is written in the manner in which Bohr likes to have the theory presented. Acknowledgments have also been made to Professors Mott and Sneddon, themselves the authors of famous textbooks.

After its triumphant entry into the arena of physics in the first two decades of the century, the theory of relativity has had a rather curious history. The special theory of relativity has become part of the daily bread-and-butter of the physicist, inasmuch as even the cheapest little electrostatic generator will accelerate electrons, so that their behavior must be described relativistically. Even nuclear particles, with their much greater masses, will exhibit some "relativistic effects" at energies of about 20 mev (ordinary cyclotrons) and will behave completely relativistically at the energies of cosmic radiation, or even at those that are achieved in the Brookhaven cosmotron. At these energies, the effective mass of the particles consists for the better part of the mass carried by their energy of motion, and their rest mass, which alone is known to ordinary mechanics, becomes less and less important. In all other respects, the behavior of these fast particles bears little resemblance to that of slow-moving bodies. When they are accelerated by some forward force, they no longer respond by increasing their speed (which cannot exceed that of light) but by increasing their mass. If such "extreme relativistic" particles are charged, they will produce both electric and magnetic fields, which are in a nearly fixed relationship to each other. All these effects are predicted in detail by the special theory of relativity, and their presentation is included in Møller's book.

The general theory of relativity, undoubtedly one of the most brilliant contributions to our understanding of the physical universe by a single scientist, has led a Cinderella life. Since its original formulation in 1916, it has been drawn on but rarely to contribute to neighboring disciplines and it has remained a field of endeavor for relatively few groups of theoretical physicists. Its positive accomplishments to date are, briefly, the explanation of the equal acceleration of all bodies in a field of gravitation (the so-called principle of equivalence); the explanation of a minute irregularity in the orbit of the planet Mercury; the prediction of the bending of light rays near the limb of the sun, observable during total eclipses and verified beyond doubt only this past year; and the prediction of a red shift of spectral lines originating close to very dense masses, such as are found in white dwarfs. In addition, the general theory of relativity has given rise to speculations in the realm of cosmology and cosmogony. These speculations rest both on theoretical possibilities unearthed by relativity and on observations on the red shift of distant nebulae. These latter observations are just being re-evaluated, and recent estimates concerning the "age of the universe" will probably have to be doubled. That such a change is at all necessary would seem to indicate that present techniques of observation and evaluation, in spite of the availability of the giant telescopes on the West Coast, are still on the ragged edge when it comes to extremely distant objects, and that the whole field of cosmology will remain speculative, although extremely fascinating, for another few decades.

In this reviewer's opinion, this period of relative obscurity is about to come to an end. Quantum field theory has now reached a stage where the emergence of new points of view alone will lead to real progress. A considerable step forward was made immediately after the second world war when Schwinger in this country and Tomanaga in Japan, and with them several other investigators, introduced consistently (special) relativistic procedures into the quantum theory of the electromagnetic field. Further progress on a fundamental level will very likely be brought about by the introduction of general-relativistic approaches into quantum field theory. This opinion is based on the fact that general relativity gives us a deeper understanding of the nature of fields and their relationships to particles than has been achieved anywhere else in theoretical physics. This understanding will be preserved by any theory that will maintain the principle of equivalence (similarity of gravitation with inertial effects, such as centrifugal "forces"), even though it may deviate in its specific details from the general theory of relativity as it was originally conceived by Einstein.

Professor Møller, whose own principal researches have been in other fields, feels sufficiently strongly about the significance of the theory of relativity that he has undertaken to write a text of the present scope. His book devotes some 200 pages to the special theory, and another 150 pages to the general theory. Beginning

with a brief historical sketch of the antecedents, he moves through the kinematic aspects of the special theory, mechanics, Minkowski universe, and electrodynamics, to complete the foundations of the special theory (five chapters). He then goes into somewhat more specialized aspects, the mechanics of continuous matter, electrodynamics in the presence of dielectric and paramagnetic substances (without nonlinear effects), and thermodynamics. In this last chapter (VII), this reviewer was slightly unhappy about the absence even of a hint that the elementary developments given are apt to be quite insufficient to deal with real situations. This is so because, for instance, the quoted early results by Planck and Einstein on relativistic thermodynamics cover only a very limited and not even very interesting class of situations, those in which one equilibrium situation develops into another equilibrium situation. Even the very moderate extension of thermodynamic inquiries usually associated with the name of Onsager (thermodynamics of stationary processes) leads beyond the framework covered by these results. Although it would be unfair to expect an introductory text to burden the reader with relatively advanced and as yet not generally known results, some indication concerning possible limitations would appear in order.

Beginning with Chapter VIII, Møller moves on to the general theory of relativity. He lays a physical and mathematical foundation in three chapters, to present and discuss the field equations of the gravitational field in Chapter XI. In this chapter, Møller discusses both the weak-field (linear) approximation and the rigorous Schwarzschild solution. In the concluding Chapter XII, finally, Møller discusses both the experimental tests referred to above and the applications to cosmology. A series of brief appendices is devoted to a derivation of a number of useful mathematical and geometric results. The two indices consume a total of three pages.

PETER G. BERGMANN
Department of Physics, Syracuse University

Theoretical Nuclear Physics. John M. Blatt and Victor E. Weisskopf. xiv + 864 pp. Illus. $12.50. Wiley, New York; Chapman & Hall, London. 1952.

IN THE terminology of another field of criticism the book *Theoretical Nuclear Physics*, by Blatt and Weisskopf, easily rates four stars. Presumably intended as a textbook for second-year graduate students—or at any rate, graduate students with a knowledge of quantum mechanics—it is an excellent text. The amount and scope of the material presented are in generous excess of what would be presented in most one-year courses, and so ample opportunity for selection is afforded. The book is more than a textbook of nuclear physics, however. It should constitute a useful reference for both graduate students and the more mature research physicist and, in the opinion of this reviewer, it will retain its usefulness for a long time to come.

A mere listing of the table of contents does not convey an adequate idea of the thoroughness nor even of the completeness with which nuclear physics has been treated in this volume. In fact, of course, it is easier to cite the justifiable omissions: meson theories of nuclear forces (the status of which is such that a discussion of this topic is best deferred for some future book) and a few borderline fields which are, for the most part, applications of nuclear theory or auxiliary topics that are useful in the interpretation of some experiments but that do not properly belong to the main subject matter (stopping of charged particles, neutron diffraction, molecular and atomic beams, and reactor theory).

Specifically, the discussion includes: A careful discussion of general properties of the nucleus, wherein the reader obtains a first orientation as to what factors are important in nuclear structure; a fairly exhaustive account of the two-body problems at both low and high energies, in which it is brought out clearly just what one may learn concerning nuclear forces from the pertinent experimental data; the conclusions with regard to nuclear forces, with emphasis on the question of saturation; the three- and four-body problems; nuclear spectroscopy, both from a general point of view, wherein symmetry considerations alone are invoked, and on the basis of the several specialized models introduced in the past; a comprehensive treatment of nuclear reactions, in terms of both the Weisskopf and Wigner theories, and the application of the theory to experiments; the spontaneous decay of nuclei, which includes α-decay, emission and absorption of γ-rays, including the capture process, and associated electromagnetic phenomena such as internal conversion, internal pairs and forbidden (nonradiative) transitions, and finally β-decay, which is presented as completely and authoritatively as any review article; a concluding chapter on the (j-j coupling) shell model. The comparative brevity of this last chapter is understandable in view of the fact that a finite time interval must necessarily exist between final revision of a manuscript and the date of publication (spring of 1951 to late summer of 1952, in this case).

In any book of this kind there is always the question of compromise between the desire to present adequate detail and the desire to keep the size of the book within reasonable bounds. It is a truism that a measure of the skill of the writing is the degree of success with which burdensome details have been sacrificed without sacrificing clarity. This is especially important in nuclear physics, with its vast literature and the necessarily rather complicated and lengthy treatments of the various theoretical problems which arise in this field. The present authors are to be congratulated in this respect. Throughout the book the arguments are presented by means of a formalism that is nicely adjusted to the requirements of clarity. The discussion of many topics has been improved, as compared to hitherto existing treatments, and a considerable amount of new material has been added in the way of a critical analysis of the various theoretical developments. Adequate references to the

literature provide ample opportunity for more detailed examination of all topics. The liberal use of figures and the lists of symbols used, which appear at the end of each chapter, are particularly helpful.

If there is any adverse criticism, it lies in the fact that there are no problems in this book. The number of misprints is reasonably small, and most of these are easily detected.

M. E. Rose

Oak Ridge National Laboratory

FRONTIERS OF RESEARCH

Progress in Organic Chemistry, Vol. I. J. W. Cook, Ed. viii + 287 pp. $7.80. Academic Press, New York. 1952.

THE goal which the editor has set himself is indicated by the following excerpt from the foreword:

> Organic chemistry has become a vast subject and new knowledge is accumulating at an ever-increasing pace. For these reasons, comprehensive accounts of advances in every phase of the subject are apt to take so long to prepare that they tend to become somewhat out of date even before they are published. The present volume has limited objectives. An attempt has been made to present in a concise but adequate form descriptions of recent developments in selected fields of organic chemistry. The selection has been based on the importance or topical interest of the subjects chosen, and it is hoped that the book will have a widespread appeal to all classes of organic chemists. It has been written primarily for research workers and advanced students, and the liberal provision of references to the original literature will be of particular value to the former class of reader. Each of the contributors is an active worker in the field which he has reviewed, and this has ensured that every chapter is fully authoritative.

This, the first volume of a new venture, consists of eight chapters covering a wide range of topics: Molecular Structure of Strychnine, Brucine and Vomicine, by Sir Robert Robinson; Chemistry of Some Heartwood Constituents of Conifers and their Physiological and Taxonomic Significance, by H. Erdtman; Photodynamically-Active Natural Pigments, by H. H. Brockmann; Chemicals from Petroleum, by S. F. Birch; Acetylene Chemistry, by B. C. L. Weedon; Drugs Inhibiting Symptomatic Stimulators, by F. Bergel and M. W. Parkes; Free Radicals as Intermediates in Organic Reactions, by D. H. Hey; Starch and its Products of Amylolytic Degradation, by I. A. Preece.

The task which Professor Cook and his collaborators have attempted is a difficult one, and chemists cannot but be grateful to them. The majority of the chapters are well written, and several are especially fine. Among the particularly clear and interesting essays are Photodynamically-Active Natural Pigments, Acetylene Chemistry, and Starch. There are, however, two chapters that are not well written and that are something less than "fully authoritative."

One of these is Chemicals from Petroleum. For example, the discussions of the hydrolysis of 1,3-dichlorohydrin (p. 111), the mechanism of vapor phase nitration (p. 128), and the pyrolysis of diallyl ether (p. 111) are not good. And one would hardly say that the section on hydration of olefins (pp. 101–105) is either accurate or modern.

The chapter on Free Radicals as Intermediates in Organic Reactions is neither lucid nor critical. For instance, the Franck-Rabinowitsch effect is invoked where it should not be invoked (p. 227); without any reservations at all, hydrogen atoms are shown as the products of aromatic substitution by free radicals—sometimes with and sometimes without a bracket around the H· (the significance of the bracket is never explained); the ionization of hexaphenylethane is incorrectly described (p. 221). Topics are discussed without any indication that they are, in reality, only poorly understood—e.g., the Meerwein reaction (p. 234). The *ad hoc* nature of the discussion is typified by the fact that on page 230 a free radical (bromine atom) is stated to be "functioning as an electrophilic reagent," whereas on page 225 a free radical (phenyl) is described as "electrically neutral" and its behavior is contrasted with that of electrophilic reagents.

The success of this series will depend on the extent to which the various contributions are critical and lucid evaluations of recent developments. It will also depend on the topics discussed. For a volume that is entitled *Progress in Organic Chemistry* there would appear to be an unduly large emphasis on natural products and pharmacology.

Nathan Kornblum

Department of Chemistry, Purdue University

Advances in Catalysis and Related Subjects. W. G. Frankenburg, V. I. Komarewsky, and E. K. Rideal, Eds. Vol. III: xi + 360 pp. $7.80; Vol. IV: xi + 457 pp. $9.50. Academic Press, New York. 1951 and 1952.

ONE of the important functions of catalysts is to overcome the inertia exhibited by many reactions in their approach to equilibrium. Another concerns the manner of approach toward equilibrium and is described as the "selectivity" of the catalyst. Where more than one reaction path is thermodynamically possible, catalysts may be found that will favor one path above others. These two functions—namely, increasing the reaction rate and selectivity—make catalysis an intriguing and important subject in science and engineering.

In 1943 a compilation of data and thinking on the entire subject of catalysis was published (*Handbuch der Katalyse,* 6 vols. G. M. Schwab, Ed. Vienna: Springer-Verlag [1943]). The current publications, *Advances in Catalysis and Related Subjects,* are intended to be chiefly reports from the frontier of research in catalysis and to serve as a stimulus for

critical thinking and experimentation in this field. Two chapters which illustrate these purposes very well are Chemical Characteristics and Structure of Cracking Catalysts, by A. G. Oblad and others in Volume III, and Chemical Concepts of Catalytic Cracking, by R. C. Hansford in Volume IV. The first paper presents a novel explanation of the mechanism of cracking of hydrocarbons by silica-alumina and similar catalysts. In this mechanism the authors postulate a periodic change of 6-coordinated aluminum to the 4-coordinated state caused by the adsorption of a weak base (such as the hydrocarbon), and return to the 6-coordinated state upon desorption of the products. In the latter paper, Hansford is critical of this mechanism and argues strongly for the existence of protons on the catalyst surface at cracking temperatures, so that the chemical reactions in cracking of hydrocarbons on this basis are essentially similar to the "carbonium ion" reactions in homogeneous acid catalysis of hydrocarbon isomerization, alkylation, etc. To orient the reader in his thinking on this subject, Volume III includes a paper on Catalytic Cracking of Pure Hydrocarbons, by V. Haensel, and Volume IV includes a paper on the Structure and Sintering Properties of Cracking Catalysts and Related Materials, by H. E. Ries, Jr., and one on Acid-Base Catalysis and Molecular Structure, by R. P. Bell. It is to be expected that these correlations of homogeneous and heterogeneous catalysis will be extended to include the important field of hydrogenation. Although examples of homogeneous catalysis of hydrogenation reactions are as yet very few in number, a comparison of their mechanisms with those in heterogeneous catalytic hydrogenation would be of much scientific and practical value.

Volume III contains also an interesting presentation of steric factors in contact catalysis in Balandin's Contribution to Heterogeneous Catalysis, by B. M. Trapnell; and a clear presentation of the use of magnetic measurements to determine the degree and type of dispersion of catalysts on various supports in Magnetism and the Structure of Catalytically Active Solids, by P. W. Selwood. Other important parts of Volume III are The Poisoning of Metal Catalysts, by E. B. Maxted; Reaction Rates and Selectivity in Catalyst Pores, by A. Wheeler; Nickel Sulfide Catalysts, by W. J. Kirkpatrick; and Catalytic Oxidation of Acetylene in Air for Oxygen Manufacture, by J. H. Rushton.

Volume IV contains, also, two outstanding contributions to our thinking on adsorption on surfaces of solids—namely, Theory of Physical Adsorption, by T. L. Hill, and The Role of Surface Heterogeneity in Adsorption, by G. D. Halsey. Also in Volume IV are chapters on Decomposition of Hydrogen Peroxide by Catalysts in Homogeneous Aqueous Solutions, by J. H. Baxendale; The Free Radical Mechanism in the Reactions of Hydrogen Peroxide, by J. Weiss; The Specific Reactions of Iron in Some Hemoproteins, by G. George; and Twenty-Five Years of Synthesis of Gasoline by Catalytic Conversion of Carbon Monoxide and Hydrogen, by H. Pichler.

One volume per year of *Advances in Catalysis and Related Subjects,* has been published since 1949. These books are of great value to those scientists and engineers interested in keeping well informed in this field. The presentation of the subject matter could be improved by restricting each volume to a particular part or branch of catalysis and including some pertinent discussion of each chapter by specialists. When one remembers that "catalysis and related subjects" includes virtually the whole realm of chemistry, it is apparent that some specialization of each volume is desirable.

HENRY H. STORCH

Fuels-Technology Division
Bureau of Mines, Region VIII
Bruceton, Pennsylvania.

THE REPUBLIC NEEDS SCIENTISTS

Antoine Lavoisier. Douglas McKie. 440 pp. $6.00. Illus. Henry Schuman, New York. 1952.

NO WONDER that Lavoisier is a favorite scientist of the biographers. In the language of his own time, what a "natural philosopher" he was: a chemist who knew how to ask of an original research the right questions so as to get significant answers, but also a physicist and a mathematician—even a geologist and a botanist of sorts.

Known quite rightly as the Father of Chemical Science, Lavoisier did not disdain to improve the manufacture of gunpowder and the street lighting of Paris. He replaced the deliberately mystic jargon of the alchemists with a sensible chemical nomenclature. He checked and revised the metric weights and measures. He outlined educational reforms far in advance of his day. In his clever hands the clumsy laboratory apparatus at his command yielded results of famous accuracy. He marshaled his facts—chemical, financial, or political—with proverbial French logic, and he wrote easily and well.

But Lavoisier was also a practical financier and a sound theoretical economist, a successful industrial executive and a prosperous farmer who turned his rather infertile acres into one of the first experiment stations. In a corrupt era, he served a bureaucrat-ridden government with wholehearted devotion to public service and with scrupulous personal honesty. He was a patriot who worked hard for the material prosperity and military security of France; a humanitarian who strove to lighten the burdens, especially the tax burden, of the poor.

Withal Antoine Lavoisier was a handsome, personable man of means, a patron of the opera, married to a beautiful, talented woman whom he adored. And in his prime, at fifty-one, he died under the guillotine.

Dr. McKie's new life of this amazing man has three great merits. It presents Lavoisier in the round. It contains new facts from original sources. It is pleasantly, effectively written.

Reading this book you need no chemistry to under-

stand Lavoisier's epochal experiments and what they meant. Neither need you be expert in French history to realize vividly the atmosphere in which he lived, the people who touched his life, the onrush of events that destroyed one of the founders of our scientific age. Here is Lavoisier as he truly was, an eighteenth-century Leonardo da Vinci; compeer and contemporary of our own great men of multiple genius, Franklin and Jefferson. While thoroughly enjoying yourself with this book, you are bound to pick up a lot of chemistry and history, to say nothing of a refreshed appreciation of the spirit of science laboring in the service of mankind. It is heartening today to recall, as McKie aptly does, how much greater influence, in the long run and for the good of us all, Lavoisier's scientific discoveries and humanitarian ideals have had during the past century and a half that did the brutal struggle for power between stubborn conservatism and stark radicalism in which he innocently lost his life.

WILLIAMS HAYNES

Stonecrop Farm
Stonington, Connecticut

MONUMENT REVISED

Illustrated Flora of the Northeastern United States and Adjacent Canada. Henry A. Gleason. Vol. 1, lxxv + 482 pp.; Vol. 2, 655 pp.; Vol. 3, 589 pp.; 4660 text figures. $27.50 postpaid until July 1; thereafter, $30.00 plus 50 cents postage. New York Botanical Garden, New York. 1952.

TWO thousand years ago a Greek philosopher cautioned critics that their function was not to air their own knowledge, "not to make talk and discourse, but to weigh and consider." To do either with regard to the new *Illustrated Flora,* which will certainly become a classic, does need a little knowledge of what led to the first edition in order to understand this one.

Over fifty years ago the late Nathaniel Lord Britton conceived the ambitious plan of a flora of the Northeastern states in which every species would have an illustration. It was a revolutionary idea for America, although it had been done for several countries in Europe. Much more revolutionary than having a picture for each plant was the Brittonian concept of what constituted a species, a genus, or a family of plants—not to mention his highly controversial attitude regarding Latin nomenclature.

Under this aegis appeared the first edition of the *Illustrated Flora* in 1896–98, and a second in 1913, which has never until now been revised, although knowledge of our flora has increased enormously. Both were issued under the joint authorship of N. L. Britton and Addison Brown, but everyone understood that the books were written by Dr. Britton, who founded, and was the first director of, the New York Botanical Garden.

The prestige of the book's author, and the brilliant future of the newly established garden, made its issuance a landmark in American botanical history. But it was a landmark with many difficult peaks, some jagged promontories, a badly eroded coastline, and a few pitfalls too deep for comfortable acceptance. One condoned these because there was no other completely illustrated flora of the region. It never deceived the knowing that these handicaps were serious, because the book embodied the Brittonian ideas outlined above, most of which have since been repudiated.

The book has long been out of print, and it was peculiarly fitting that the Board of Managers of the New York Botanical Garden, in May 1939, should have authorized the publication of a completely rewritten and revised edition of Britton and Brown's *Illustrated Flora.* It is this that has just been issued.

The selection of the author for such a major undertaking was most fortunate. Henry A. Gleason, by lifelong training in systematic botany, seems the one inevitable man to make the revision what it is, and perhaps the best qualified to appraise all that was worth retaining from the old edition, reject most of the Brittonisms, and add the salient features that modern research has uncovered since 1913. He has done this immense job with such brilliant success that the book will be a classic for the next fifty years.

Competence to complete such a task calls for qualities that are not often found among botanists. The book is necessarily technical, for how could it be otherwise when 4660 species, and many varieties, are described and keys provided for their identification? If that were all, the amateur might think the book too difficult to use or too time-consuming to be worth the effort. Dr. Gleason has made hundreds of decisions that help to simplify an admittedly difficult problem—that of making the book technically above reproach and at the same time making it available to the inquiring amateur.

THE SCIENTIFIC MONTHLY is not the place, nor does it have the space, to go into the details of such a large book, but one illustration of Gleason's viewpoint is worth quoting. For years sharp-eyed specialists have detected about 400 of what they call "species" of blackberries and their relatives. It is a truism that most of these exist only in the minds of their authors, and, as Gleason points out in his introduction, "it is not necessary that all such minor groups be given names." He admits just 24 species of *Rubus,* knowing well that each of them is a complex of highly variable brambles, the nomenclatorial designation of which does not help science but enormously confuses everyone.

Although comparisons are usually invidious, they are necessary for anyone who wants to decide whether to buy the new *Illustrated Flora* or its only possible rival —the recently issued eighth edition of *Gray's Manual,* by the late M. L. Fernald. Perhaps the best answer is that Fernald admits 205 "species" of *Rubus,* Gleason 24. To specialists who will say that the Gleason treatment is inadequate, one might venture the reminder that there is such a thing as knowing more and more about less and less. There are scores of other genera in both books that differ in this fundamental concept,

the best illustration of which is that *Gray's Manual* contains 5523 "species" whereas the new *Illustrated Flora* comprises only 4660. "Species," as Gleason well knows, are merely concepts of convenience, not immutable entities in nature. He has kept that steadily in mind in his revision.

Users of the new *Illustrated Flora* will find many changes. The illustrations are now grouped by genera, on pages and half-pages, and this makes for convenience in contrasting related species. All the old synonyms have been omitted, but any change in name, as between this edition and older standard reference works is always noted.

A valid English name is supplied for all plants that have one, but hundreds of so-called common names, like "cordate-leaved aster," "setose violet," etc., have rightly been killed. A curious omission is for *Albizzia julibrissin,* which Gleason calls "acacia," but which is universally called "mimosa" in Washington—both names, of course, being incorrect! Also, he uses *Wisteria* instead of *Wistaria,* thought by most to be the correct spelling for a plant named for Caspar Wistar. The correct vernacular name for *Daphne mezereum,* also, is "mezereon," not "mezereum."

Other misprints could doubtless be found by anyone who wants to look for such flyspecks upon a monumental and outstanding undertaking, but such minutiae will never obscure the fact that the Garden and Dr. Gleason have put us all under that kind of obligation for which there are no adequate words except, perhaps, "Well done, and thank you!"

NORMAN TAYLOR
Elmwood, Princess Anne, Maryland

PALEOECOLOGIC SYNTHESIS

Histoire Géologique de la Biosphère, la Vie et les Sédiments dans les Géographies Successives. Henri Termier and Geneviève Termier. 721 pp. Illus.; maps. Paperbound, 9600 French fr; clothbound, 9200 French fr. Masson & Cie., Paris. 1952.

PROFESSOR and Mme. Termier, of the University of Algeria, have written a scholarly, original, and timely book. It is the best paleoecologic synthesis to date and may well initiate a brand-new academic approach to the teaching of earth history. The authors set themselves the enormous task of summarizing the vast data on the biosphere through all geologic time. To have produced a useful work on so immense a subject, the data for which are so diffusely seeded through the literature of stratigraphic geology and paleontology, within the covers of a 700-page book, bespeaks immense powers of concentration and synthesis. As with all such attempts, the specialist will instantaneously find ample grounds for complaint. Carefully prepared bibliographies will help in some measure to furnish documentation otherwise omitted. To the European-North African experience of the authors can be attributed the consistently more satisfactory treatment of the Old World than of the New and of Asia.

The book is divided into two unequal sections. The first (260 pp.) treats in an excellent manner with general geographic, geologic, sedimentary, and ecological matters as related to the biosphere. The second part traces the successive geographies of the earth's history. The 35 colored world paleogeographic structural maps that illustrate this section are valuable generalizations. To be sure, like all such attempts, the representations are highly controversial, the while being undoubtedly the best thing so far drafted. To this reviewer the Termier treatment of trans-Atlantic passage of the Paleozoic geosynclines is quite unsatisfactory. However, to each his own bias! Too bad the French language (as well as the price) will stand as a barrier to North American students. The world picture, painted in broad strokes so well by the Termiers, is exactly the general knowledge lacking in current English language texts of historical or general geology. Happily, there will be no language barrier to fullest understanding of the fine maps.

In addition to her labors as co-author, Mme. Termier has prepared the excellent illustrations. The maps are of striking conception and excellent execution, although some other projection than the Mercator would have been a better base for the geographies. The line figures are clear and telling. However, the full-page original lithographs, although of undoubted artistic merit, do not contribute sufficiently to warrant the considerable additional cost which their inclusion has most certainly meant. It is a pity that a book of such potential usefulness is so exorbitantly priced.

KENNETH E. CASTER
Department of Geology, University of Cincinnati

INTUITIVE GEOMETRY

Geometry and the Imagination. D. Hilbert S. Cohn-Vossen, xi + 357 pp. Illus. $5.00. Chelsea Publishing Co., New York. 1952.

Auschauliche Geometrie has been a classic for twenty years. Its breadth of outlook is reminiscent of Klein's *Elementary Mathematics from an Advanced Standpoint.* Although it deals with elementary topics, it reaches the fringe of our knowledge in many directions. This excellent translation by Dr. Neményi may help to restore interest in geometry, a subject that seems lately to have lost favor in America.

The first chapter (The Simplest Curves and Surfaces) provides a synthetic introduction to conics and quadrics, including the construction for a central quadric by means of a loop of thread pressing against the focal conics: the solid analog of the familiar thread construction for an ellipse.

The second (Regular Systems of Points) is an original treatment of lattices and quadratic forms, sphere packing, crystallographic groups, and regular polyhedra. The drawings of polyhedra are unusually perspicuous because of the clever device of exaggerated perspective: an

edge not parallel to the picture plane appears thicker at the near end and thinner at the far end.

The third chapter (Projective Configurations) gives a clear account of the configurations n_3 consisting of n points and n lines, 3 points on each line, 3 lines through each point. These exist in the complex plane for $n > 7$, and in the real plane for $n > 8$. The cases $n = 9$ and $n = 10$ include the figures for the theorems of Pappus and Desargues, which play an important role in the foundations of geometry. Then comes a well-illustrated description of Reye's three-dimensional configuration of 12 points, 16 lines, and 12 planes, and a superb drawing (p. 152) of the related four-dimensional polytope {3, 4, 3}. Another very successful drawing is that of Schläfli's double-six of lines on page 165.

The fourth chapter (Differential Geometry) leads the reader gently into various ramifications of the theory of curvature, including the spherical image, monkey-saddles, minimal surfaces, stereographic projection, and non-Euclidean geometry, all without any explicit use of coordinates or vectors or tensors. Figure 204 is a reproduction of Klein's model of the Apollo Belvedere, with all the parabolic curves marked on the face and neck. Another remarkable feature of this chapter is the section on "Eleven Properties of the Sphere," some of which serve to characterize the sphere and others are unexpectedly found to be shared by different surfaces.

The fifth chapter (Kinematics) begins with Peaucellier's inversor (which enables one to draw a straight line in a given plane without using a ruler) and an analogous three-dimensional linkage, with universal joints, for constructing a plane. This leads naturally to a discussion of continuous rigid motion and of roulettes, including R. C. Yates' instrument for constructing the meridian of a surface of revolution having constant positive Gaussian curvature.

The sixth chapter (Topology) contains a classification of two-sided and one-sided surfaces in terms of the "connectivity" h, which is related to the Euler-Poincaré characteristic by the formula $V - E + F = 3 - h$ (cf. W. W. R. Ball's *Mathematical Recreations and Essays*, 11th ed., p. 232). We find here a description of Boy's surface, which is closed and one-sided with $h = 2$ (like the projective plane) and yet has no singular points nor any points of discontinuity of curvature, although of course it intersects itself along certain curves. (The only way to avoid self-intersection is to work in four dimensions; this is done in an appendix.)

The only serious error of translation is the omission of the words, "of motions" from page 87, fourth line from the bottom. Some readers might be confused by a typographical error in the first two lines of page 264, where z and $\bar{z}$ should be interchanged. In a few places errors of the German edition have been carried over. The most serious of these is on page 92 (second line from the bottom), where "octahedral" should be "tetrahedral." In the footnote to page 290 we read that "whereas every closed convex polyhedron is rigid, there are closed non-convex polyhedra whose faces can be moved relative to each other." The only such figure known to the reviewer (see W. W. R. Ball, *op. cit.*, p. 153) is not a legitimate example, as some of its edges coincide in pairs.

But these are mere criticisms of detail, hardly worthy of mention in a book having such an extraordinarily high concentration of interesting ideas and information. It is a sad thought that neither the original publisher nor the heirs of the authors can benefit from the sale of this edition.

H. S. M. Coxeter

Department of Mathematics
University of Toronto

BRIEFLY REVIEWED

Unit Processes in Organic Synthesis. (4th ed.) P. H. Groggins, Editor-in-Chief. xiii + 937 pp. Illus. $12.50. McGraw-Hill, New York. 1952.

THE fourth edition of this well-known text resembles the third in general excellence and differs from it in only a few respects. The principal contributors, W. P. Hamner (Hydrolysis), and M. Orchin and W. C. Shroeder (Hydroformylation), have replaced four others who contributed to the previous edition. A new chapter on the currently interesting oxo reaction (Hydroformylation) has been added. Each of the old chapters has been retained but brought reasonably well up to date. There is increased emphasis on aliphatic compounds, on the economics of manufacture, and especially on theoretical aspects such as the kinetics and thermodynamics of industrial reactions.

The book is fairly free of errors, although the reviewer objects to such things as the repeated use of two charges on ions that are actually singly charged—e.g., pp. 21 and 26; the statements, "the volume of which is not over 2,000 lb."—p. 153; and, "When the alcohol has a neopentyl group as in *tert*-butyl alcohol . . ." and the inconsistencies in nomenclature and reaction mechanism which always seem to be present in compilations of the works of a number of different authors.

This member of the McGraw-Hill Chemical Engineering Series belongs in the private libraries of most chemical engineers and many organic chemists.

G. B. Bachman

Department of Chemistry, Purdue University

Polarography, Vol. II. (2nd ed.) I. M. Kolthoff and James J. Lingane. 588 pp. Illus. $11.00. Interscience, New York–London. 1952.

THE first volume deals with Theoretical Principles and with Instrumentation and General Methods. Part Three, which begins Volume II, consists of a thorough systematic review of the polarography of 72 elements. In most cases sufficient details and data are

given so that recourse to the original literature becomes unnecessary. This part is concluded with a chapter in which selected procedures are presented in detail for the analysis of various types of alloys and other technical materials.

Part Four, which deals with the polarography of organic substances, was written with the assistance of Stanley Wawzonek, who is thoroughly acquainted with polarography of organic compounds. This section is exceptionally well done in 10 chapters. One may obtain an idea of the wide variety of compounds discussed by mentioning a few section headings: aldehydes, 3-ketosteroids, organic acids, nitro compounds, amines, pyran derivatives, alkaloids, penicillin, and chlorophylls.

Biological applications of polarography are discussed in Part Five, written with the aid of W. Stricks. Part of this chapter is devoted to Serological Applications of Catalytic Waves for the Diagnosis of Cancer. Part Six presents amperometric titrations. This section clearly indicates the tremendous progress of this new technique since the first edition of this text.

An author and subject index for both volumes is given at the end of Volume II.

The authors have performed a great service to those who use polarographic methods of analysis by systematically arranging a voluminous amount of material scattered in the literature. These volumes are also an excellent source for those who wish to know more of this intriguing method of analysis.

THOS. DE VRIES
Department of Chemistry, Purdue University

The Growth and Development of the Negro in Dentistry in the United States. Clifton Orrin Dummett. $5.00. Printed by the Stanek Press, Chicago, for the National Dental Association. 1952.

THE story of the struggles of the American Negro to throw off the shackles of slavery and prejudice and to take his rightful place in world affairs has always been an impressive saga. This book describes the difficulties and obstacles met by those of that race who seek to elevate themselves to a professional level in the field of dentistry. These obstacles are dealt with in a frank and forthright manner, and the present status of the Negro in dentistry is very clearly presented.

Through the years the Negro, especially in the South, has been handicapped by inadequate educational facilities and financial resources from engaging in graduate study. Those who were able to continue their education in order to qualify in the fields of science and literature were faced with racial prejudice and the inability to gain entrance to schools of higher learning. All along the way their progress has met with opposition, and they have succeeded only by overcoming great odds.

Although handicapped by inferior preliminary education and lack of financial support, many Negroes have overcome these difficulties and have become well-qualified practitioners and teachers in the field. At the present time there are two Negro schools, Howard and Meharry, and 22 other schools have accepted a limited number of Negro students.

The Negro dentists have their own national organization, the National Dental Association, and in many states are accepted in the American Dental Association. In Howard University five Negro teachers hold Ph.D. and M.D. degrees, and in Meharry there are four teachers who hold Ph.D. degrees. Three other dental schools have Negro teachers on their staff, and eleven have signified their willingness to employ qualified Negro teachers. Negro dentists are also represented in the U. S. Public Health Service and the Veterans Administration.

With present-day decreasing racial discrimination and the recognition of the equality of man, many of the former hindrances to dental education for the Negro are disappearing. Now there is need for encouragement of young men of that race who have the educational background to engage in the study and practice of dentistry. They are greatly needed for the care of their own race, and many could serve the dental needs of the white population.

Opportunities should be opened for a larger enrollment of Negroes in dental schools. Negro leaders do not believe that this can be accomplished by the creation of additional segregated schools. Rather, they favor increased support and enlargement of the two existing Negro schools; also, that all dental schools should open their doors to well-qualified Negro students on the same basis as to whites.

Dr. Dummett's book is well worth reading. The history of the advancement of our Negro confreres in dentistry cannot fail to stir our sympathy and admiration for what they have been able to accomplish. It should also stimulate greater interest and active cooperation in helping them to take their rightful place in dental health services.

R. W. BUNTING
School of Dentistry
University of Michigan

Child Psychotherapy. S. R. Slavson. 332 pp. $4.50. Columbia University Press, New York. 1952.

THIS is a veritable guidebook and manual for social workers, psychiatrists, case workers, psychologists, intelligent parents, and all others who are concerned with children. The author is director of group therapy at the Jewish Board of Guardians of New York, and consultant for the Youth Consultation Service, the Newark Child Guidance Clinic, and the Council Child Development Center. He is also editor of the *International Journal of Group Psychotherapy* and chairman of the Commission on Group Therapy of the World Federation of Mental Health.

In the preface to *Child Psychotherapy,* he says that, although his book is primarily intended as a clinical study, with special emphasis upon the treatment process of the emotionally disturbed and socially maladjusted child under twelve years of age, he found it advisable

to point out other elements as well. The book is divided into three main parts—Development, Pathogenesis, and Psychotherapy—and is the outcome of four decades of work with people in many relationships and settings (the majority were children and adolescents). It also reflects twenty years of clinical experience that favored learning, experimentation, and reflection.

Slavson himself says that many of the ideas contained in the volume just published may not be new, but he hopes that new vigor and meaning are given by a "fresh restatement in a different context, in new relations and in the integrative approach to the bio-psychosocial entity that is man."

A very important chapter outlines the personal qualifications, educational background, skills, and functions of the psychotherapist. The last chapter, Treatment of a Neurotic Nine-Year Old Boy with Organic Deficiency, is a case study (25 pp.) of Harry Peters, with a summary of the psychiatric case workers' treatment. The case is taken from the files of the Child Guidance Institute of the Jewish Board of Guardians, New York. The volume contains other case histories, although they are not as complete as the one describing the treatment of the neurotic nine-year-old.

Your reviewer wishes to emphasize that Slavson's *Child Psychotherapy* is a "must" book for social workers, particularly group workers and all others who deal intensively with youth.

PHILIP L. SEMAN

Sociology Department
The University of Judaism, Los Angeles

Hydrogen Ion Concentration. John E. Ricci. xxxvi + 460 pp. $10.00. Princeton University Press, Princeton, N. J. 1952.

PROFESSOR RICCI begins by stating that the formulas usually used for calculating the hydrogen ion concentration of aqueous solutions have been obtained by derivations from loosely held postulates. He proposes that it is in a certain sense simpler and certainly better to derive exact mathematical relations for the hydrogen ion concentration and then to simplify these, if warranted. He has been able to derive these exact relations without significant reference to special theories of ionization. He has given us a rigorous and thorough mathematical treatment of the hydrogen ion concentration of various aqueous solutions. The reader is required only to attend diligently to the lengthy arguments, which are presented in an ordered manner.

This book cannot easily be used as a reference (and this seems to be its primary purpose) for a particular question about pH or a related phenomenon until the user has rather carefully perused the entire book. Such a condition could be cause for criticism, but in this case it follows as a necessary consequence of the rigorous manner in which the subject is treated, although the occasional use of unfamiliar terms for familiar concepts and the very large number of symbols used, listed, and defined (on pp. xxvii–xxxv) tend to make the difficult task of understanding somewhat less pleasant than it could have been. The humorless and occasionally disputatious style used by the author also does nothing to enhance the readability of the work.

Briefly, the relation between hydrogen ion concentration and the concentrations of solutes present in solution is derived by combining equations pertaining to the net ionic charge, degree of ionization of the solute, the ion product of water, etc. Generally, this yields an equation of high degree in $[H^+]$, simple to derive, but laborious to solve for a numerical value of $[H^+]$. The author describes a simple procedure for solution of the equations. The last five chapters treat solubility of electrolytes and its relation to pH as applied to the separation of one solute from another and to precipitation titrations. Among the chapter headings are:

Definitions and Fundamental Relations; the Theorem of Isohydric Solutions; Limits of Ionization Fractions and the Iso-electric Point for Solutes and Ampholytes; Calculation of the Numerical Value of H from the General Equations Titration (with Strong Base or Strong Acid) in Mixtures Involving any Number of Independent Ionization Constants; Titration with Weak Acid or Weak Base; Problems Involving Two Interdependent Ionization Constants; Tribasic Acids; Salts with Strong and Weak Bases; Saturation with Respect to Acids and Bases; Pure Saturated Aqueous Solution of a Salt; Saturation with Salts of Monobasic Acid; Saturation with Salts of Dibasic Acid; and Saturation with Ampholytes and their Salts.

A thorough treatment of hydrogen ion concentration relations in aqueous solutions has long been due, and Ricci is to be complimented for undertaking the arduous task of laying out the broad principles of approach. It is hoped that others will follow him in further developing this approach.

JAY A. YOUNG

Department of Chemistry, King's College
Wilkes-Barre, Pennsylvania

The Petroleum Dictionary. Lalia Phipps Boone. xiii + 338 pp. $5.00. University of Oklahoma Press, Norman. 1952.

HERE is a rich and rewarding book for the dialectician, the colloquialist, and the folklorist, a disappointing book for the scientist or the engineer. The author's field is linguistics. She has taught school in the oil fields, is married to an oil man, and has lived in the oil country for many years. Her long-time interest has been the picturesque language of the oil man; she says in her preface, "Its freshness, its peculiarities, and its vividness fascinate me today." Those qualities she has succeeded in capturing, first in the discussion of usage and sources in Part One, "The Language of the Oil Field" (37 pp.), and, second, in many of the definitions in Part Two, "The Petroleum Dictionary" (299 pp.).

Unfortunately, in her technical and semitechnical

definitions, she has not always captured the accuracy on which the smooth operation of the oil industry depends. This is not surprising; chemistry is the only science to which the author confesses—and some of her chemical definitions are questionable. She says, "I have concentrated my attention primarily upon non-technical usage." Her technical definitions attest the truth of the statement; so do some of her semitechnical ones.

In the following random examples, technical, semitechnical, and nontechnical, the italics are the reviewer's:

Acre-foot: An acre of land 1 foot wide and 43,560 feet long.

Anticlinal axis: The line on a geological map which indicates the axis of a fold.

A.P.I. gravity: The gravity specified by the American Petroleum Institute.

Asymmetric anticline: An anticline without plane or symmetry which lacks proportion in the parts.

Bituminous sandstone: Any rock formed of coherent or cemented sandstone.

Catalyst: The chemical agent in the presence of which petroleum products are cracked.

Oil refining: The process of removing undesirable impurities from crude or partly finished oils; generally a distillation process combined with a simple chemical treatment.

Old age: Strata which are considered to be many ages old. Some strata have eroded or weathered more than others.

Red beds: A sticky red shale belonging to the Wichita formation of the Permian series.

A *geologist* is a "bird dog, exploration crew, geoilogist, mud smeller, pebble picker, pebble pup, rock hound, rocksy, roxy, sand smeller, smeller, wrinkle chaser." Each of these terms is defined, but under none of them is a geologist defined. Your reviewer still wonders what he really is.

MAX W. BALL

1025 Vermont Ave., N.W.
Washington, D. C.

Sun, Moon, and Planets. Roy K. Marshall. x + 129 pp. Illus. $2.50. Henry Holt, New York. 1952.

THIS reasonably priced booklet is written for the general public and contains answers to many of the questions that intelligent laymen might ask about the solar system. As far as this was the aim of the author, he succeeded and has produced an account which reads easily and should not be beyond the grasp of anyone who is sufficiently interested to wish to read about our solar system at all.

The art of writing popular books on scientific topics is extremely difficult, and one seldom finds a volume that does not fall into either of two traps. These two pitfalls are, on the one hand, the oversimplification and underestimation of the powers of elementary reasoning of the public and, on the other hand, assuming knowledge which is elementary to the expert but often unavailable to the layman. In my opinion, Dr. Marshall has not been able to avoid either of these. To give a few examples, all from Chapter 2: the author states Kepler's third law and discusses as an instance the pair Pluto-Mercury and then goes on to say "arithmetic is a little more difficult for other pairs," which seems to me to be an instance of treating his readers as if they were nursery school pupils. On the other hand, the foci of an eclipse are mentioned (and the phonetic spelling of the word "foci" given) without explaining the meaning of the focus of an eclipse, and similarly the term "eccentricity" is introduced without further explanation. A final instance is the following statement in the discussion of Kepler's third law: "Newton showed that there were small deviations to be found in working out Kepler's Third Law, and that these were due to different masses of the planets. Because the sun is so much more massive than any of the planets . . . the earlier investigators did not have a chance to detect these small deviations." This statement seems to be rather cryptic for laymen.

Altogether, I feel that this book, which probably will reach a vast public, could have gained very much if the author had taken slightly more trouble in preparing it. Popularizing science is not equivalent to abandoning the rigor of an argument, and this booklet contains too many loosely phrased sections which could easily be rigorized without destroying their understandability.

Algebraic Technique of Integration. (2nd ed.) Harris F. MacNeish. viii + 133 pp. $2.50. Wm. C. Brown Co., Dubuque, Iowa. 1952.

THIS booklet gives a comprehensive survey of integration methods. The methods of integrating rational functions, rational fractions (by using a streamlined method), and functions of trigonometric, hyperbolic, and irrational functions are treated in detail, and many examples are given. A new method, that of "logarithmic integration," is discussed, and examples of its application are given.

The book includes a discussion of elliptic integrals and beta and gamma functions, and should be a useful guide for anyone who needs to evaluate integrals that are sufficiently different from the standard ones not to be included in the usual tables.

Radio Astronomy. Bernard Lovell and J. A. Clegg. 238 pp. Illus. $4.00. Wiley, New York. 1952.

IT IS seldom realized that the earth's atmosphere is practically completely opaque to electromagnetic waves of nearly all wavelengths. There are, however, two "windows," one in the visible region extending only very slightly into the infrared and ultraviolet, the other extending from about 0.25 cm to 20 m. Although the first window has been used since time immemorial for astronomical observations, only the great improvement in radio techniques during the past war made it possible to use the second window and gave rise to the new

science called "radio astronomy." The present account of this science is written by the professor of radio astronomy in Manchester University and one of his associates at the Jodrell Bank Experiment Station. The authors have attempted successfully to write in such a way that as wide a circle of readers as possible may get an idea of the importance, aims, and results obtained so far by radio astronomy.

After a few introductory chapters on the basic ideas of astronomy and radio techniques, the study of meteors by radio techniques is discussed in great detail, and it is shown how this new technique has greatly improved our knowledge of the "shooting stars." The emission of radio waves from the sun, their possible origin, and the problems connected with these phenomena are discussed in Chapters 12–15.

Although in meteor and solar physics radio astronomy merely supplements the older astronomical methods, radio emission from our galaxy has led to many new and still not completely understood phenomena. The most striking example was the discovery of the so-called radio stars—that is, centers of greatly enhanced radio emission at positions where no ordinary stars can be found. It is amusing to read that these radio stars twinkle as do their commoner relations, and for the same reason—atmospheric irregularities.

The last chapters of the book deal with the aurora borealis, the moon, planets, and Gegenschein.

Altogether this book gives a comprehensive, lucid account that can be recommended to all people interested in recent developments in physics or astronomy. The style is easy, and mathematics is kept to a minimum. The only point where I differ from the authors is on the subject of references, and I would like to have seen a list of references as a separate appendix, which would not have broken the continuity of the text and would have increased even further the usefulness of this volume.

Advances in Electronics, Vol. IV. L. Marton, Ed. x + 344 pp. Illus. $7.80. Academic Press, New York. 1952.

THE fourth volume in this series lives up to the high standard the editors have set themselves. It contains seven contributions dealing with subjects as varied as electron scattering in solids and multichannel radio telemetering. Extensive indices enhance the usefulness of the volume.

In the first article Massey gives a comprehensive account of electron scattering in solids. He deals especially with elastic, inelastic, and multiple scattering, energy loss and electron mobility in metals, alloys, and semiconductors. The article is a pleasure to read. The author points out deficiencies in our knowledge and gives an extensive bibliography.

The second article, by Morton, deals with the scintillation counter. It is hard to imagine that this widely used piece of equipment is only five years old. After dealing first with more general principles, the article concludes with a discussion of applications of the scintillation counter.

Van der Ziel discusses in his article fluctuation phenomena and, more specifically, the different kinds of noise that occur in diodes, triodes, gas-discharge tubes, photocells and photomultipliers, semiconductors, transistors, and so on. The discussion is mainly theoretical and seems to cover nearly every conceivable case of noise. A comprehensive bibliography in three sections (textbooks, survey articles, and research papers) concludes this contribution.

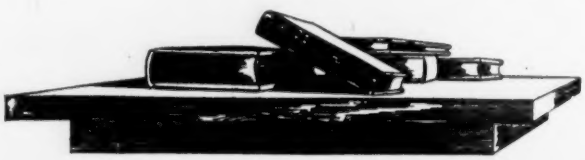
The next contribution, by C. V. L. Smith, discusses electronic digital computers. Alas, there is no bibliography, but the reader is referred to another treatise on the same subject. After a general introduction dealing with the principles involved in the planning of an electronic computer, the author describes in detail the Whirlwind and SEAC computers, which are now operating satisfactorily. Apart from the omission of references, this contribution is one of the best and most instructive in the volume. Donal describes in his article the modulation of continuous-wave magnetrons.

One of the methods used during the last war to spot submarines was by measuring the change in the earth's magnetic field that are due to the ferromagnetic body of the submarine by means of magnetic airborne detectors. These instruments, their mode of operation, and the difficulties encountered in their use are discussed by Fromm.

Another subject that owes much of its development to wartime requirements is that of multichannel radio telemetering. A telemeter is an instrument for measuring one or more quantities, transmitting the result to a distant station and then indicating or recording the quantities measured. From this definition one sees the importance of telemetering for aircraft development, since these instruments can be used to record data during the flight of pilotless models. The development of multichannel telemetering is described by Pawley and Triest in the last article of this excellent volume.

D. TER HAAR

Department of National Philosophy
The University, St. Andrews, Scotland



ASSOCIATION AFFAIRS

CONSTITUTION AND BYLAWS

AT ITS first session at St. Louis on Dec. 27, 1952, the AAAS Council passed the revised Constitution and new Bylaws without a dissenting vote. Although both documents were published in SCIENCE 116, 575 [1952]), the Constitution stipulates that they be reprinted in both Association journals and also that they become effective one month from the date on which Council action was taken—January 27, 1953. Hereafter, and until amended, the work of the Association and its officers will be governed by the Constitution and Bylaws as printed below:

Constitution

Article I

Section 1. The American Association for the Advancement of Science was incorporated by an act of the General Court of the Commonwealth of Massachusetts in 1874. The Association is a nonprofit scientific and educational body.

Section 2. The objects of the American Association for the Advancement of Science are to further the work of scientists, to facilitate cooperation among them, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.

Article II

Section 1. The membership of the Association shall consist of Members, Fellows, and Associates. Individuals in any of these three groups may become life members, emeritus members, and sustaining members in accordance with the provisions of Section 5 of this Article and with such relevant rules as the Board of Directors shall have prescribed.

Section 2. Members. Any person, institution, or organization may be admitted to the grade of Member. Each Member shall have such rights and privileges and shall pay such annual dues and fees as the Council shall have prescribed.

Section 3. Fellows. Any person who shall have made a meritorious contribution to science may become a Fellow of the Association under such procedures as the Board of Directors shall have prescribed.

Section 4. Associates. Any person who shall have a record of leadership in any field related to science and who wishes to cooperate in the advancement of science may become an Associate of the Association under such procedures as the Board of Directors shall have prescribed.

Section 5. (*a*) *Life Members.* Any person making the Association a life-membership contribution of such amount as the Board of Directors shall have prescribed may be admitted to life membership. Each Life Member shall be exempt from the payment of annual dues and shall have all the privileges of an annual member throughout life.

(*b*) *Emeritus Members.* Any individual annual member may be admitted to emeritus membership under such conditions as the Board of Directors shall have prescribed. Each Emeritus Member shall be exempt from the payment of annual dues and shall have all the privileges of an annual member throughout life.

(*c*) *Sustaining Members.* Any person making to the Trust Funds of the Association a sustaining membership contribution of such amount as the Board of Directors shall have prescribed shall be the founder of a Sustaining Membership, which shall bear his name and shall be maintained in perpetuity as a trust. Each incumbent of a sustaining membership shall have all the privileges of a life member. The first incumbent of a sustaining membership may be either the founder himself or another person named by him, as he may choose. On the death or resignation of an incumbent, the Board of Directors shall name another person to hold the membership throughout life.

Article III

Section 1. The officers of the Association shall be (*a*) general officers elected from among the Fellows by ballot of the Council, and (*b*) administrative officers elected by the Board of Directors as prescribed in Section 3 of this Article.

Section 2. General Officers. The general officers of the Association shall be a president-elect, a president, a retiring president, and a vice president for each section. The term of office of the president-elect and of the vice presidents shall begin on the January 15 following their election. At the close of the one-year term of the president-elect he shall become president, and at the close of the one-year term of the president he shall become retiring president. In the event of a vacancy in the office of the president, the president-elect shall become president. In the event of a vacancy in the office of president-elect, the Board of Directors shall make a pro tempore appointment to hold until the vacancy shall have been filled by ballot of the Council. In the event of a vacancy in the office of vice president the Board of Directors shall fill the vacancy by appointment.

Section 3. Administrative Officers. The administrative officers shall be an administrative secretary, one or more associate or assistant secretaries, a treasurer, and, in addition, a secretary for each section. The administrative secretary, the associate or assistant secretaries, and the treasurer shall be elected by the Board of Directors. The secretaries of the sections shall be nominated from among the Fellows by the respective section committees and elected by the Board of Directors. The terms of office of each administrative officer shall be determined by the Board of Directors. The Board of Directors shall fill vacancies in the administrative offices.

Section 4. The duties of the officers shall be customary to those of the office and as further defined in the bylaws.

Article IV

Section 1. The Council shall perform duties prescribed

in the constitution and shall act as an advisory body in matters pertaining to the general policies of the Association.

Section 2. The Council shall consist of (*a*) the president-elect, the president, the retiring president, the vice presidents, the secretaries of the sections, the administrative secretary, the treasurer, and the eight (8) elected members of the Board of Directors; (*b*) one Fellow elected by each regional division of the Association; and (*c*) the representatives of affiliated organizations as provided in Article VIII of this constitution. Each Council member shall serve until his successor shall have taken office. The president shall be chairman of the Council; if the president shall be unable to serve as chairman at any session, the Council members in attendance shall elect a chairman for that session. Twenty (20) members of the Council shall constitute a quorum for the transaction of business.

Section 3. The Council shall meet during the annual meeting of the Association and at other times on the call of the president or upon the written request of twenty (20) members of the Council.

Article V

Section 1. The Board of Directors is the legal representative of the Association and as such shall have, hold, and administer all the property, funds, and affairs of the Association.

Section 2. The Board of Directors shall consist of eleven (11) members, the president-elect, the president, the retiring president, and eight (8) Fellows elected by the Council, two each year, for a term of four years. At any election of members of the Board of Directors not more than one Fellow serving his fourth consecutive year as an elected member may be re-elected. In the event of a vacancy in the office of an elected member of the Board of Directors, his successor for the remainder of the year shall be elected from among the Fellows by the Board of Directors and, for the remainder of the unexpired term, his successor shall be elected by the Council at the next annual election. Five (5) members of the Board of Directors shall constitute a quorum for the transaction of business. The retiring president of the Association shall be chairman of the Board of Directors. If he shall be unable to serve at any session of the Board, the Board members in attendance shall elect a chairman for that session. The administrative secretary and treasurer shall be ex officio members of the Board of Directors without vote.

Section 3. The Board of Directors shall hold four (4) meetings each year, one of which will be at the annual meeting. The Board of Directors shall also meet at the call of the chairman.

Section 4. The Board of Directors shall appoint such committees as may be necessary to aid in the management of the Association. The duties of standing committees shall be stated in the bylaws.

Section 5. The term of office of each of the eight (8) regularly elected members of the Board of Directors shall begin on January 15 following his election, and each shall serve until his successor shall have taken office.

Article VI

Section 1. The Association shall be organized in sections in accordance with the fields of interest of its members, as determined by the Council. Each member of the Association may designate the section in which he wishes to be enrolled and may designate an additional section in which he is interested.

Section 2. The vice president for a section shall be ex officio chairman of that section.

Section 3. The affairs of each section shall be managed by a section committee consisting of (*a*) the chairman and secretary of the section; (*b*) other members of the Council whose professional interests are in the field covered by the section or who represent societies affiliated with the section; and (*c*) four (4) Fellows, one elected each year by the section committee for a term of four (4) years. No person shall serve concurrently in more than one section committee. If an elected member of a section committee shall have resigned or died, his successor for the remainder of the unexpired term shall be elected from among the Fellows by the Board of Directors from nominations made by the section committee. One third of the members of the section committee shall constitute a quorum for the transaction of business.

Section 4. The section committee of each section shall promote the work of the Association in its own field and may organize subcommittees for that purpose. It shall arrange such section programs as it shall deem desirable for meetings of the Association, either separately or in cooperation with other sections of the Association or with independent societies. With the approval of the Board of Directors a section committee may arrange section meetings to be held at places and times other than those of Association meetings.

Article VII

Section 1. Regional divisions and local branches of the Association may be authorized by vote of the Council, for the purpose of promoting the work of the Association in their respective territories.

Section 2. Each regional division or local branch shall elect its officers for such terms as it shall prescribe and shall hold its meetings and conduct its affairs as it shall deem desirable, subject to the relevant provisions of this constitution and of the bylaws of the Association, and to such special provisions as the Board of Directors of the Association shall have established.

Article VIII

Section 1. To facilitate cooperation between the Association and other organizations, and among the latter, the Council may, on recommendation of the Board of Directors, elect an organization to be an official affiliate.

Section 2. Each organization thus designated an affiliate shall be entitled to name one Fellow of the Association to represent it on the Council; if it has more than 100 members who are Fellows of the Association, it shall be entitled to name an additional Fellow to represent it on the Council.

Section 3. On recommendation of the Board of Directors, the Council may elect an organization to be an official associate. Associated organizations shall have the same rights and privileges as affiliated organizations except for representation on the Council.

Article IX

Section 1. The Association shall hold an annual meeting at such time and place each year as the Board of Directors shall have determined. Other meetings of the Association or of its sections may be authorized by the Board of Directors.

Article X

Section 1. The publications of the Association shall be

issued in such manner as the Board of Directors may direct.

Article XI

Section 1. Funds of the Association shall be classified as Current Funds, Investment Funds, and Trust Funds.

(*a*) *Current Funds* shall include all dues of annual members, all receipts from publications, and all other funds received in the continuing operations of the Association.

(*b*) *Investment Funds* shall include all gifts and bequests received without special restriction concerning the use to be made of principal and income, and such other funds as may be designated by the Board of Directors as investment funds.

(*c*) *Trust Funds* shall consist of all life-membership contributions, all sustaining-membership contributions, all funds appropriated by the Board of Directors for establishing special life memberships, all gifts and bequests accepted with specific restrictions prohibiting their allotment to either Current Funds or Investment Funds, and such other funds as may be designated by the Board of Directors as Trust Funds.

Section 2. The deposit, investment, and disbursement of all funds shall be subject to the direction of the Board of Directors.

Article XII

Section 1. Amendments to this constitution shall be approved by the Board of Directors after publication in substance in SCIENCE and THE SCIENTIFIC MONTHLY at least one month prior to an annual meeting of the Association and ratified by a two-thirds vote of the Council members present in a Council session of that meeting. Ratified amendments shall be effective upon adoption and shall be published promptly in SCIENCE and THE SCIENTIFIC MONTHLY.

Bylaws

Article I

Section 1. The objects of the Association shall be accomplished by conducting meetings and conferences of those interested in various branches of science and education, producing and distributing publications, administering gifts and bequests as prescribed by the donors thereof, supporting research, making awards to recognize accomplishments in science, cooperating with other organizations in the advancement of science, and engaging in such other activities as shall have been authorized by the Board of Directors.

Article II

Section 1. Members who have paid dues for fifty years may be excused from further payments and still retain all the privileges of membership.

Section 2. Members may be elected by the Board of Directors to be Fellows of the Association and Fellows so elected shall remain Fellows only so long as they retain membership. If a Fellow discontinues his membership and subsequently rejoins the Association, he shall automatically again become a Fellow from the time of rejoining, without another election. Members are eligible to nomination for fellowship if they have contributed to the advancement of science either by the publication of original research or in other significant manner. Nominations for election to fellowship may be made by any three Fellows or by the administrative secretary or by the section committee in whose field the nominee's scientific work mainly lies.

Section 3. A Member may be dropped from membership for conduct which in any way tends to injure the Association or to affect adversely its reputation or which is contrary to, or destructive of, its objects. Charges of injurious conduct shall not be entertained against a Member unless the precise nature of the charges be submitted in writing to the president of the Association by not fewer than two Members. Upon receipt of such charges, the president shall refer them to the Executive Committee, which shall have the power to determine whether the charges shall be dropped, whether the accused shall be given an opportunity to resign, or whether the charges shall be referred to the Board of Directors for review and for final disposition. Whenever charges are referred to the Board of Directors, no person shall be dropped from membership except after opportunity to be heard and then only by a three-fourths vote of those members of the Board of Directors present and voting at a regular or special meeting.

Article III

Section 1. The administrative secretary shall serve as secretary to the Council and to the Board of Directors; he shall be in charge of the Association's offices and shall manage the affairs of the Association in accordance with procedures determined by the Board of Directors. He shall be an ex officio member of all standing committees.

Section 2. The treasurer shall perform the usual duties and those assigned in the bylaws.

Section 3. Reports of the administrative secretary and the treasurer shall be made in the manner prescribed by the Board of Directors.

Article IV

Section 1. The committees shall be standing as provided in the bylaws or special as the Board of Directors approves.

Section 2. During the interim between meetings of the Board of Directors, an Executive Committee consisting of the retiring president, the president, the president-elect, and such other directors or administrative officers as the Board of Directors may designate shall act on behalf of the Board of Directors. All actions taken by the Executive Committee shall be submitted for review and action at the next following meeting of the Board of Directors.

Section 3. The Investment and Finance Committee shall advise the Board of Directors regarding purchases and sales of securities for the Association, shall make recommendations to the Board of Directors on financial questions, and shall have the authority to buy or sell securities under such limitations as the Board of Directors may set. The Investment and Finance Committee shall consist of the treasurer, the administrative secretary, and five (5) members appointed by the Board of Directors. Each appointed member shall serve a term of five (5) years, the term of one member expiring on January 14 of each year. Each shall serve until his successor shall have taken office.

Section 4. The Committee on Affiliation and Association shall review applications for affiliation or association with the Association and make recommendations thereon to the Board of Directors. The committee shall consist of five (5) members appointed by the Board of Directors.

Each member shall serve a term of five (5) years, the term of one member to expire on January 14 of each year. Each shall serve until his successor shall have taken office.

Section 5. The Publications Committee shall give continuing scrutiny to the publications of the Association and the policies pertaining thereto and shall make recommendations thereon to the Board of Directors. The committee shall consist of five (5) men appointed by the Board of Directors. Each member shall serve a term of five (5) years, the term of one member to expire on January 14 of each year. Each shall serve until his successor shall have taken office.

Article V

Section 1. Council representatives of affiliated organizations which are not specifically related to an established section of the Association may be assigned to section committees in accordance with their requests.

Article VI

Section 1. Regional divisions authorized by the Council have full control of their meetings, of their affiliations with other scientific organizations, and of all activities to promote the advancement of science in their territory.

Section 2. The Pacific Division (organized in 1915) includes members of the Association resident in British Columbia, Washington, Oregon, California, Idaho, Nevada, Utah, and the Hawaiian Islands.

Section 3. The Southwestern Division (organized in 1920) includes members of the Association resident in Arizona, New Mexico, Colorado, Sonora, Chihuahua, and Texas west of the 100th meridian.

Section 4. The Alaska Division (organized in 1951) includes members of the Association resident in Alaska.

Section 5. Each division shall receive for its expenses an annual allowance not to exceed one dollar for each of its members in good standing and shall make an annual report to the Board of Directors covering its financial situation and other activities.

Article VII

Section 1. The names of affiliated and associated organizations shall be published from time to time as directed by the Board of Directors.

Section 2. Affiliated academies of science shall receive for research an annual allowance of fifty cents for each of their members who is also a member in good standing of the Association. The minimum annual allowance shall be fifty dollars. If any academy fails to utilize the research funds made available to it in any one year, these funds shall revert to the Association's treasury on December 31 of the second calendar year following the year in which the allowance was computed.

Article VIII

Section 1. The programs and arrangements for the Association meetings shall be under the general direction of the Board of Directors.

Article IX

Section 1. The publications of the Association shall be (*a*) SCIENCE, (*b*) THE SCIENTIFIC MONTHLY, (*c*) *Proceedings*, and (*d*) such other special publications as the Board of Directors may direct.

Section 2. The Association shall not be responsible for statements or opinions advanced in papers or in discussions at meetings of the Association or its sections, divisions, or branches, or printed in its publications.

Section 3. The Association reserves the right to copyright, at the discretion of the Board of Directors, any of its papers, discussions, reports, or publications.

Article X

Section 1. All funds shall be paid into the business office of the administrative secretary, where they shall be entered in the books of the Association, and deposited in a bank designated by the Board of Directors. The treasurer shall be the custodian of all Investment Funds, Trust Funds, and such other funds as may be placed in his charge by the Board of Directors. The administrative secretary shall be the custodian of the current funds.

Section 2. All bills against members and others shall be made and collected by the business office of the administrative secretary.

Section 3. All expenditures shall be made in accordance with the budget of appropriations as adopted by the Board of Directors.

Section 4. All payments shall be made by the business office upon competent certification as to their correctness and proper authorization.

Section 5. Checks against the accounts of the Association will bear two signatures, from a list of individuals determined by the Board of Directors.

Section 6. The securities of the Association may be bought, sold, or exchanged only upon the written order of two of the following: the chairman of the Investment and Finance Committee, the vice-chairman of the Investment and Finance Committee, the treasurer, and the administrative secretary.

Section 7. The business office of the administrative secretary shall keep proper accounts of all financial transactions of the Association.

Section 8. The accounts of the Association shall be audited and approved annually by a certified public accountant selected by the Board of Directors.

Section 9. The administrative secretary shall have the authority to enter into contracts for the Association, but contract authorizations must be within the budget authorizations made by the Board of Directors.

Section 10. The activities of the Gordon Research Conference shall be administered according to procedures established by the Board of Directors.

Article XI

The bylaws may be amended by majority vote of the Board of Directors, provided notification of the proposed amendment has been mailed to each member of the Board at least twenty (20) days prior to the meeting. Changes made in the bylaws by the Board of Directors shall be subject to approval, by majority vote, of the Council.

HOWARD A. MEYERHOFF

Administrative Secretary, AAAS